ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support -- 1989

D. P. Haradem
J. R. Gauger
J. E. Zapotosky

Technical Report E06620-5
Contract No. N00039-88-C-0065
October 1990

Prepared for:

Submarine Communications Project Office
Space and Naval Warfare Systems Command
Washington, D.C. 20363-5100

Submitted by:

IIT Research Institute
10 West 35th Street
Chicago, Illinois 60616-3799

IITRI

Printed in the United States of America

This report is available from:

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE NA/NA	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) E06620-5	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION IIT Research Institute / 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Chicago, Illinois 60616-3799	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Space and Naval Warfare Systems Command / 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER N00039-88-C-0065
8c. ADDRESS (City, State, and ZIP Code) Washington, D.C. 20363-5100	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1989 (Unclassified)

12. PERSONAL AUTHOR(S)
D. P. Haradem, J. R. Gauger, J. E. Zapotosky

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Technical	FROM 1983 TO 1989	1990 October	317

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Extremely Low Frequency; Ecology; Electromagnetic Fields; ELF Communications System; Environmental Studies; ELF Ecological Monitoring Program

19. ABSTRACT (Continue on reverse if necessary and identify by block number)
Ecological studies to examine for possible effects to resident biota from operation of the Navy's ELF Communications System continued in Northern Wisconsin and the Upper Peninsula of Michigan during 1989. Monitoring studies were selected through a peer-reviewed, competitive bidding process in mid-1982, and work on most studies began in late summer of that year. Preliminary activities of the Program consisted of site selection, characterization of critical study aspects, and validation of assumptions made in original proposals. Subsequently, increasing emphasis has been placed on the collection of data for treatment/-control and preoperational/operational comparison of biological parameters. All data collection near the Naval Radio Transmitting Facility-Clam Lake, Wisconsin was completed by the end of 1989, while data collection at the Naval Radio Transmitting Facility-Republic, Michigan is anticipated to continue through 1991. To date, investigators

(Continued on reverse side)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code) / 22c. OFFICE SYMBOL

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

19. ABSTRACT (Continued)

conclude that the electromagnetic (EM) fields produced by either an intermittently energized or a fully operational ELF transmitting facility have had no measurable effects on exposed biota.

This report documents EM field values at those study sites still active during 1989, and is comprehensive for the period 1983 through 1989. It also describes other engineering activities performed in support of the biological and ecological studies.

FOREWORD

This report documents measurements of extremely low frequency (ELF) electromagnetic (EM) fields made in support of the U.S. Navy's ELF Communications System Ecological Monitoring Program from 1983 through 1989. The report also describes other engineering activities in support of the Program. This work was funded by the Space and Naval Warfare Systems Command, Submarine Communications Project Office, under Contract Numbers N00039-81-C-0357, N00039-84-C-0070, and N00039-88-C-0065, to IIT Research Institute (IITRI). IITRI measurement personnel for 1989 were Messrs. D. P. Haradem, J. R. Gauger, R. G. Drexler, M. W. Zankl, J. A. Rubino, and Dr. J. E. Zapotosky.

Respectfully submitted,
IIT RESEARCH INSTITUTE

D. P. Haradem
Research Engineer

J. R. Gauger
Engineering Advisor

J. E. Zapotosky, Ph.D.
Senior Scientist

Approved:

R. D. Carlson
Program Manager

CONTENTS

CONTENTS (continued)

FIGURES

FIGURES (continued)

TABLES

ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM: ELECTROMAGNETIC FIELD MEASUREMENTS AND ENGINEERING SUPPORT--1989

1. INTRODUCTION

1.1 Ecological Monitoring Program

In 198[illegible], concurrent with its decision to complete construction of an Extremely Low Frequency (ELF) Communications System, the Department of the Navy established an Ecological Monitoring Program. The purpose of the program is to determine whether long-term exposure to electromagnetic (EM) fields produced by the communications system will result in adverse effects on resident biota or their interrelationships. Monitoring studies are being performed by investigators from several universities, and their efforts are supported by IIT Research Institute (IITRI).

IITRI assists the investigators by making EM field measurements and providing other EM engineering support. Measurements are needed to ensure significant differences in EM exposure between paired study sites and to provide data that may be needed for further examination of possible cause-and-effect relationships. EM engineering support provided by IITRI includes design, fabrication, and installation of EM control and EM recording equipment for culture chambers; mitigation of EM exposures in laboratories; and mitigation of on-site, ambient monitoring equipment with respect to EM safety, EM interference, and damage from nearby lighting strikes. IITRI personnel collect and summarize data on the operational characteristics of the ELF transmitters, perform reviews of the use and presentation of EM data in reports by investigators, and document all of these support activities annually in an IITRI technical report.

This report documents EM engineering support activities during 1989 and provides a comprehensive summary of EM exposures at study sites and laboratories over the period 1983-1989.

1.2 ELF Communications System

The ELF Communications System consists of two transmitting facilities, one located in the Chequamegon National Forest in Wisconsin and the other in the Copper Country and Escanaba River State Forests in Michigan (see Figure 1). Each facility consists of a transmitter connected to long overhead wires (antennas) with buried ground terminals at their ends. Both the antenna and grounding elements are located in cleared rights-of-way (ROW). The Naval Radio Transmitting Facility-Clam Lake, Wisconsin (NRTF-Clam Lake) consists of a north-south (NS) and an east-west (EW) antenna, each 14 miles long. The Naval Radio Transmitting Facility-Republic, Michigan (NRTF-Republic) consists of a 28-mile-long NS antenna and a 28-mile-long EW antenna. The EW

60297/790

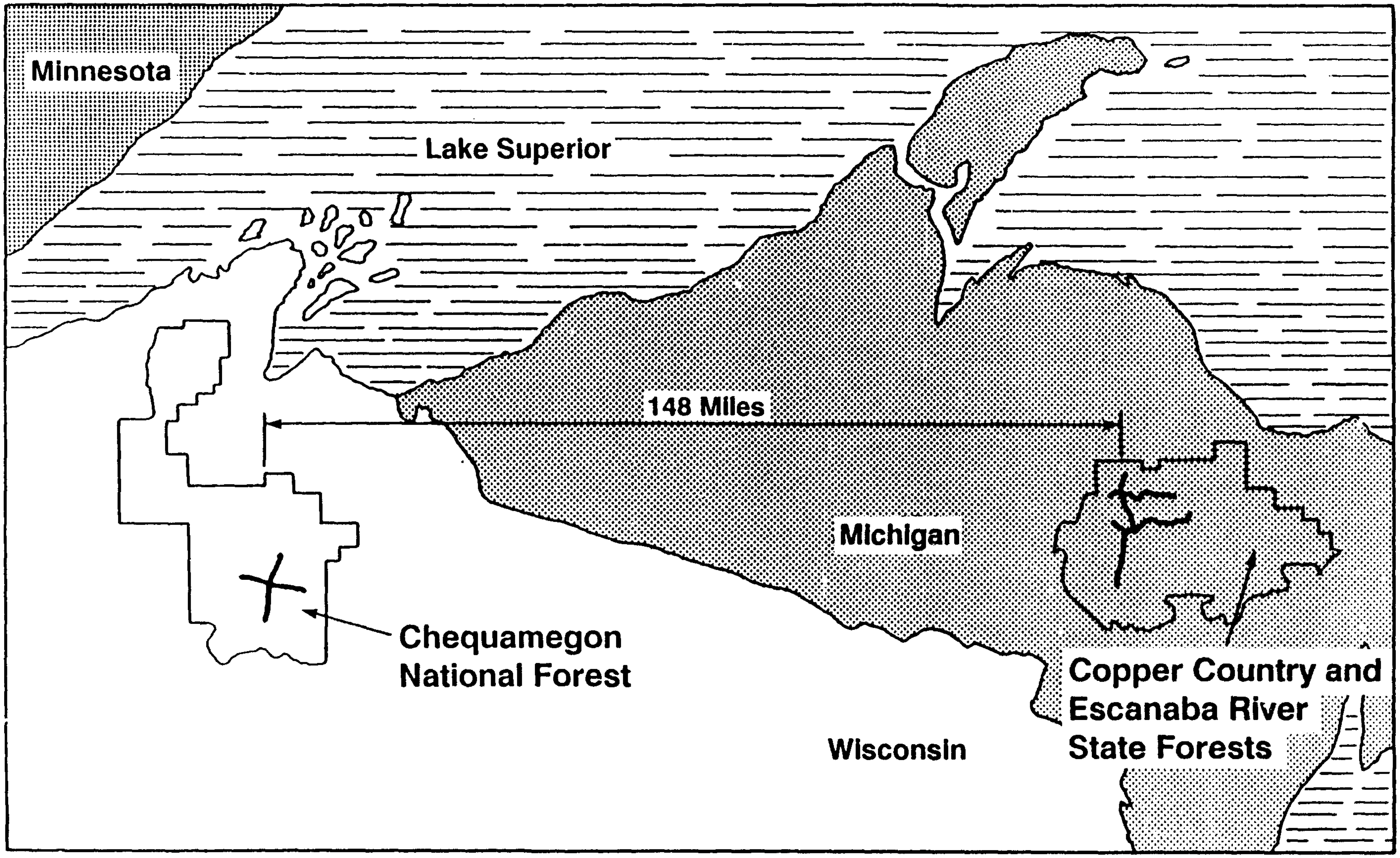


FIGURE 1. ELF COMMUNICATIONS FACILITIES IN WISCONSIN AND MICHIGAN.

antenna is comprised of a northern east-west (NEW) and a southern east-west (SEW) element, each of which is approximately 14 miles long. The end of each antenna or antenna element terminates in one to three miles of buried horizontal ground wire and several vertical wells.

The transmitters broadcast messages using ELF EM fields; these fields are the operational component to be evaluated by the Ecological Monitoring Program. The EM fields produced by the ELF Communications System are:

- a magnetic field, essentially the same in air and the earth, that is generated by the electrical current in the antenna elements and ground terminals
- an electric field in the earth that is the sum of the fields induced by the magnetic field and the current flowing from the buried ground terminals
- an electric field in air that is produced as a result of the difference in potential between the antenna element and the earth

The frequency produced by an operational ELF Communications System is modulated using minimum shift keying (MSK), a special form of frequency shift keying. An important aspect of MSK modulation is that minimal energy is generated outside the signal bandwidth. The transmitted message is binary coded: If a zero is to be transmitted, the frequency of the current is 72 Hz; for a one, the frequency is 80 Hz. The center frequency is therefore 76 Hz, and is the frequency with the greatest power spectral density. The planned frequencies for routine operation of the ELF Communications System are modulated between 72 and 80 Hz; in addition, the system can also transmit at frequencies between 40 and 48 Hz (44 Hz center frequency). Figure 2 illustrates an MSK waveform and its corresponding binary code and power spectral distribution.

Exposure of resident biota to 76 and 44 Hz EM fields has been quite variable over the development of the ELF Communications System. In order to address these differences, some ecological investigators have divided EM exposure into preoperational, transitional, and operational periods. During the preoperational phase, biota received no EM exposure from the ELF system. The transitional phase began with the energizing of a transmitter for testing; EM exposures were intermittent and most often at intensities lower than from a fully operational ELF system. During the operational phase of the ELF system, EM exposures are nearly continuous and at planned, full-power intensities. The NRTF-Clam Lake was first energized in 1969 and became fully operational during the last quarter of 1985; the NRTF-Republic was first energized in early 1986 and became fully operational during the last quarter of 1989.

1.3 Paired-Site Concept

In order to examine for possible effects, the monitoring program employs a split-plot design that compares data collected at a control site with data collected at a treatment site. Paired sites have matched biotic and environmental factors, but purposely dissimilar 76 Hz EM exposures. The

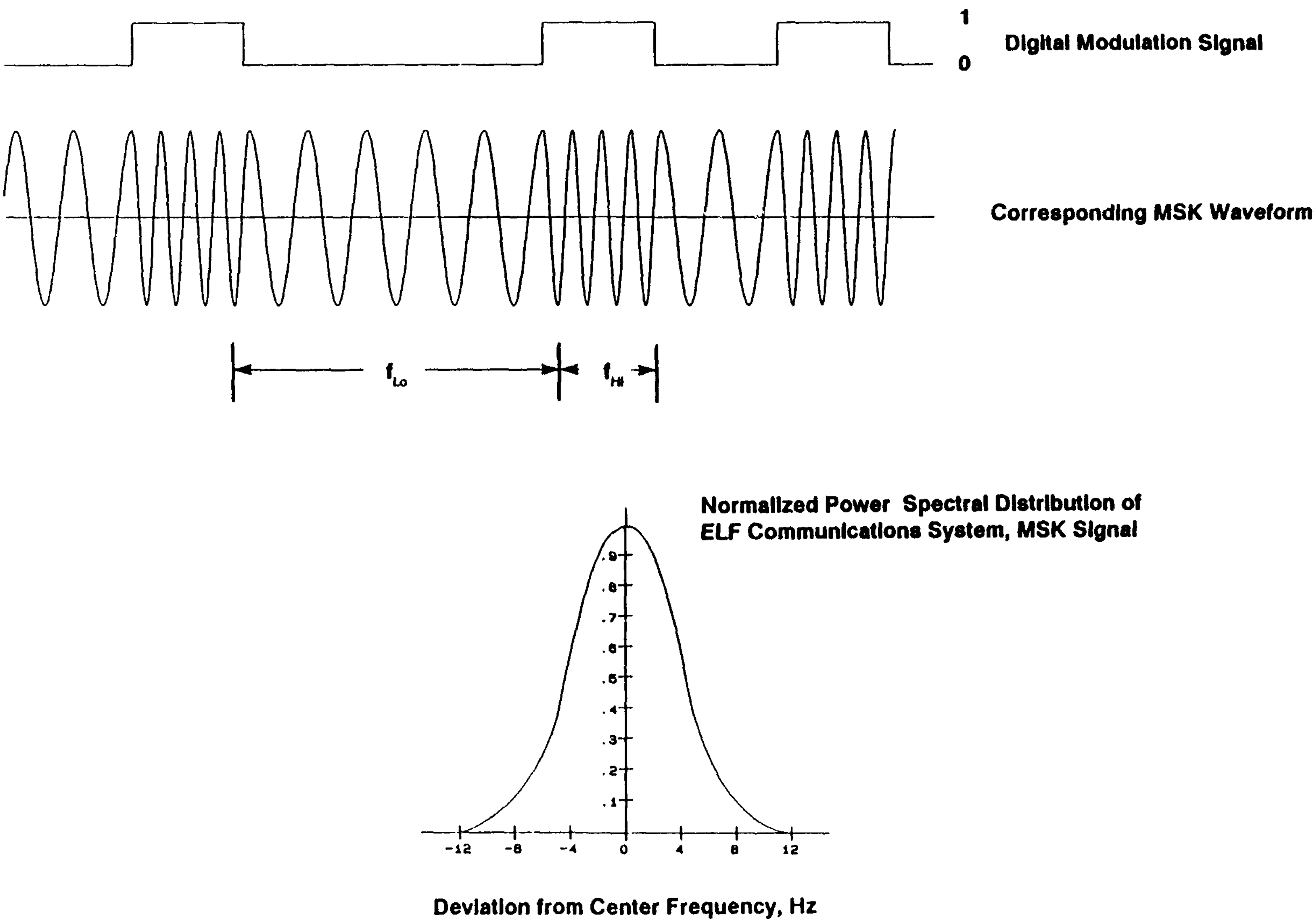


FIGURE 2. MSK WAVEFORM AND POWER SPECTRAL DISTRIBUTION.

control site is used to measure the effects of environmental factors on study variables. Variables at the treatment site express the effects of environmental factors as well as possible effects from exposure to higher 76 Hz EM fields.

Dissimilar 76 Hz EM exposures were attained by situating treatment sites relatively close to the ELF Communications System while placing control sites at a greater distance. The EM exposure criteria used in site selection are expressed in equation form as follows:

$$T_{(76\ Hz)}/C_{(76\ Hz)} > 10 \qquad (1)$$

$$T_{(76\ Hz)}/T_{(60\ Hz)} > 10 \qquad (2)$$

$$T_{(76\ Hz)}/C_{(60\ Hz)} > 10 \qquad (3)$$

$$0.1 < T_{(60\ Hz)}/C_{(60\ Hz)} < 10 \qquad (4)$$

where $T_{(76\ Hz)}$ = test site exposure due to ELF Communications System
$T_{(60\ Hz)}$ = test site exposure due to power lines
$C_{(76\ Hz)}$ = control site exposure due to ELF Communications System
$C_{(60\ Hz)}$ = control site exposure due to power lines

By means of these criteria, the monitoring program sought to ensure that the intensities of the 76 Hz EM fields at treatment sites were significantly greater than those at control sites (Equation 1); that the 76 Hz EM field intensities at treatment sites were significantly greater than the 60 Hz EM field intensities at both treatment sites (Equation 2) and control sites (Equation 3); and that there was no significant difference in 60 Hz EM fields between treatment and control sites (Equation 4).

Nearly all site pairs met or exceeded the EM exposure criteria. In a few exceptional cases, pairs came close, but failed to meet the criteria. Because the sites could not be relocated without also impacting matched biotic considerations, they were accepted.

At the NRTF-Republic, temporal comparisons will be made between the preoperational and operational phases of the ELF Communications System in addition to the spatial comparisons of treatment and control sites. Only spatial comparisons could be made at the NRTF-Clam Lake, because the transmitter has been operating since 1969 and no preoperational data base exists.

In Wisconsin, field work for slime mold and wetlands studies was completed in 1987. Complete documentation of EM field measurements and engineering support for these studies was

presented in previous annual reports[1-6] and therefore does not appear in this report. Final reports for these studies have also been published.[7-8] Only a bird species and communities study remained active in Wisconsin in 1988-1989. Study investigators in Michigan have collected their preoperational data and are moving toward the operational phase of their studies as the test currents at the NRTF-Republic are increased and operation becomes more frequent.

1.4 Annual Measurements of EM Fields

IITRI performs an annual survey to measure the EM fields at each study site. Annual measurements of 60 Hz and 76 Hz EM fields are required in order to document changes in EM exposure at study sites from year to year. Ambient 60 Hz EM fields have changed due to the construction of new power lines, variations in the local use of electric power, and the presence of the ELF antennas themselves, which have been shown to couple and reradiate 60 Hz EM fields. The 76 Hz EM field intensities produced by the ELF Communications System have changed because of reconfiguration of antenna elements and because of testing at different antenna currents. In 1989, 76 Hz EM exposures were also influenced by the simultaneous operation of both antennas, a system configuration not present in previous years.

Other EM aspects that have been examined during the annual surveys include the measurement of 60 Hz and 76 Hz harmonics, EM field levels produced at Michigan study sites due to the operation of the NRTF-Clam Lake, and EM field values as a function of the phase angle between antennas. The former two aspects were examined and found to be below detection levels or so low that they are not considered to be a confounder in treatment versus control comparisons. The latter aspect--the effect of the antenna phase angle on EM exposures--is of concern only for sites in close proximity to multiple antenna elements, and usually affects only the longitudinal electric field. Phase measurements at the NRTF-Clam Lake are treated in Appendix I. The effects of the antenna phase angle on EM exposure at Michigan study sites have not yet been characterized.

1.5 1989 Engineering Support

IITRI has provided a variety of engineering support in response to specific needs of individual researchers. These support activities are summarized here; details appear in Section 4.

Special attention has been given to the characterization and reduction of EM field exposures at the laboratories of the small mammals and nesting birds and native bees studies. Laboratory EM field exposures were initially reduced by establishing a holding facility, in a low-EM field environment, near the laboratories. Researchers for the small mammals and nesting birds studies began using the holding facility in 1987-1988, and researchers for the native bees studies began using it in 1989. In 1989, after the researchers' laboratory studies were completed, efforts were made to

reduce magnetic and electric field intensities in the small mammals and nesting birds laboratory and to reduce the electric field intensities in the native bees laboratory.

The soil amoeba studies use buried culture cells that isolate study organisms from the surrounding soil. IITRI personnel reviewed the proposed design of the culture cells in 1983, and found two areas of concern to be the matching of internal to external EM fields and the measurement of internal EM fields. IITRI subsequently designed and fabricated the culture cell exposure control apparatus to address the field-matching problem, and assisted the study investigator with field setup and installation. In 1988, IITRI fabricated and installed improved exposure control equipment and also designed and fabricated microprocessor-controlled data loggers and installed them at each study site. The data loggers made hourly measurements of the voltage and current of each culture cell, the longitudinal electric fields at each site, and the temperatures in the partially buried data logger housings. The data logger monitoring provides documentation of any variations in the culture cell electric fields or current densities that might result from factors such as rainfall, changes in temperature, or changes in the conductivity of the culture cell growth medium. In 1989, control programs for the data loggers were modified to accommodate a new operating pattern for the NRTF-Republic. Hardware modifications were also made, including the addition of two soil temperature probes at each site.

IITRI provided special assistance in 1988 to the upland flora and soil microflora studies, which use extensive and sophisticated ambient monitoring systems at each of their study sites. Analyses were conducted to estimate the magnitudes of ELF voltages that would be induced on cabling and equipment, the impact of these voltages on personnel safety, and the possibility of ELF Communications System interference to the monitoring systems. Field measurements of the induced ELF voltages were made at low-power antenna operation to verify the analyses. Work was then performed at the study sites to eliminate potential safety problems and mitigate ELF interference.

IITRI also conducted an extensive design analysis of the lightning protection required for the monitoring systems, made recommendations for reconfiguration of system grounding, and provided specifications for terminal protection equipment. IITRI then assisted the study investigators in implementing the system reconfiguration and installing the protection devices. In 1989, impedance measurements were taken again at all ground rods installed. The previously treated ground rods were then retreated with magnesium sulfate, and impedance measurements were taken again at these ground rods.

Researchers for the upland flora and soil microflora studies observed differences in aspen growth rates at their antenna study sites from 1986 to 1988. In order to test the correlation between EM field exposures and aspen growth rates, a more detailed characterization of the EM field variation across their treatment sites was needed. Measurement points were added at the antenna and

ground study sites in 1989 from which field gradient plots were drawn and used to estimate EM field intensities across the entire group of study sites. A still more detailed characterization of these sites is planned for 1990.

The EM exposure ratios for two of the aquatic ecosystems study elements, insect substrates and periphyton grazing, were low in 1989 as they had been in previous ratio determinations. IITRI made suggestions for site relocations that would improve these ratios. Also in 1989, EM field measurements were made at a 138 kV transmission line under which fish swim in movement studies. The 60 Hz EM field intensities at this location were the greatest of all in the aquatic ecosystems study region. Recommendations were therefore given for the addition of a fyke net between the ELF antenna and the transmission line to separate the possible effects of these elevated 60 Hz fields from ELF and lower 60 Hz EM fields.

The bird species and communities studies use 20 census transects, each of which is 200 m (600 ft) wide and 4.5 km (2.7 mi) long. Ten such transects are located in the NRTF-Clam Lake area and 10 near the NRTF-Republic. The study investigators requested information of the variability of the EM fields along the study transects, and also on the EM field gradients as a function of distance to an antenna element out to a distance of 400 m. During the annual EM measurements in 1988, IITRI personnel measured the EM field gradients along a line perpendicular to an NRTF-Clam Lake antenna element. They also made EM field measurements at regular intervals along one randomly chosen test and control transect pair in Wisconsin. In 1989, EM field measurements were made at regular intervals along the remaining four test transects in Wisconsin.

Temporal variations of the EM fields at study sites over the course of a year are of concern because most study biota remain on the study sites throughout the year. IITRI addressed this question in 1988 by installing six sets of fixed longitudinal electric field probe electrodes at the soil amoeba study sites. The data loggers used to monitor culture cell exposures were also used to measure the longitudinal electric fields at these electrodes. The data loggers, installed in 1988, remain at the study sites. An analysis of the longitudinal electric field variations near an antenna row and a ground row over the course of this study is presented in Section 4.4.1. The ELF magnetic fields at study sites are expected to show little or no seasonal variation, because they are dependent only on fixed antenna parameters and are not affected by surrounding soil or vegetation.

In order to accommodate Navy fleet operations, the testing of new hardware, and the testing of utility interference mitigation, both the NRTF-Clam Lake and the NRTF-Republic have operated at numerous frequency, modulation, and power conditions. IITRI maintains a computer data base of operation data and provides summaries to investigators. The operational summary is intended for use by investigators, in conjunction with annually measured EM field values at the study sites, to construct EM exposure regimes.

2. ECOLOGICAL MONITORING STUDY SITES

Selection of treatment and control sites in both Wisconsin and Michigan began in 1983 under the criteria described in Section 1.3. In Wisconsin, actual measurements of 60 Hz and 76 Hz EM fields were used to check adherence of the candidate sites to the established criteria. Because sites in Michigan were chosen prior to the completion of the NRTF-Republic antennas, their selection was based on measurements of 60 Hz EM fields and preoperational estimates of the 76 Hz EM fields that were prepared using engineering models of the proposed Michigan ELF antennas. The Michigan antennas were completed in 1986, and 76 Hz measurements were then possible for the first time. Measurements made in 1986 verified the acceptability of the Michigan treatment and control sites: all sites were confirmed to be either acceptable or conditionally acceptable, as defined in Appendix H.

The locations of study transects for the Wisconsin bird species and communities studies relative to the NRTF-Clam Lake antennas are shown in Figure 3.

The locations of sites for the Michigan studies relative to the NRTF-Republic antennas are shown in Figure 4. The seven studies in Michigan are identified in the upper left-hand corner of this figure. Collection sites for red maple leaves and pine needles do not appear in the figure, because they are beyond the range of the map shown.

The study sites in Michigan include treatment and control sites as well as other special sites, namely, laboratory sites, a holding facility, displacement sites, and foliage collection sites. The small mammals and nesting birds studies and the native bees studies share a holding facility that is used to house animals in a low-EM field environment, near the study laboratories, prior to laboratory testing. The small mammals and nesting birds studies also employ displacement sites from which animals' movements back to the study site are measured. The upland flora and soil microflora studies make use of remote locations to collect foliage samples, which are brought back to the study sites. EM field exposures at all of these special sites are important because they confound exposures at the treatment and control sites. They have, therefore, been included with treatment and control sites in the annual measurement regime for Michigan.

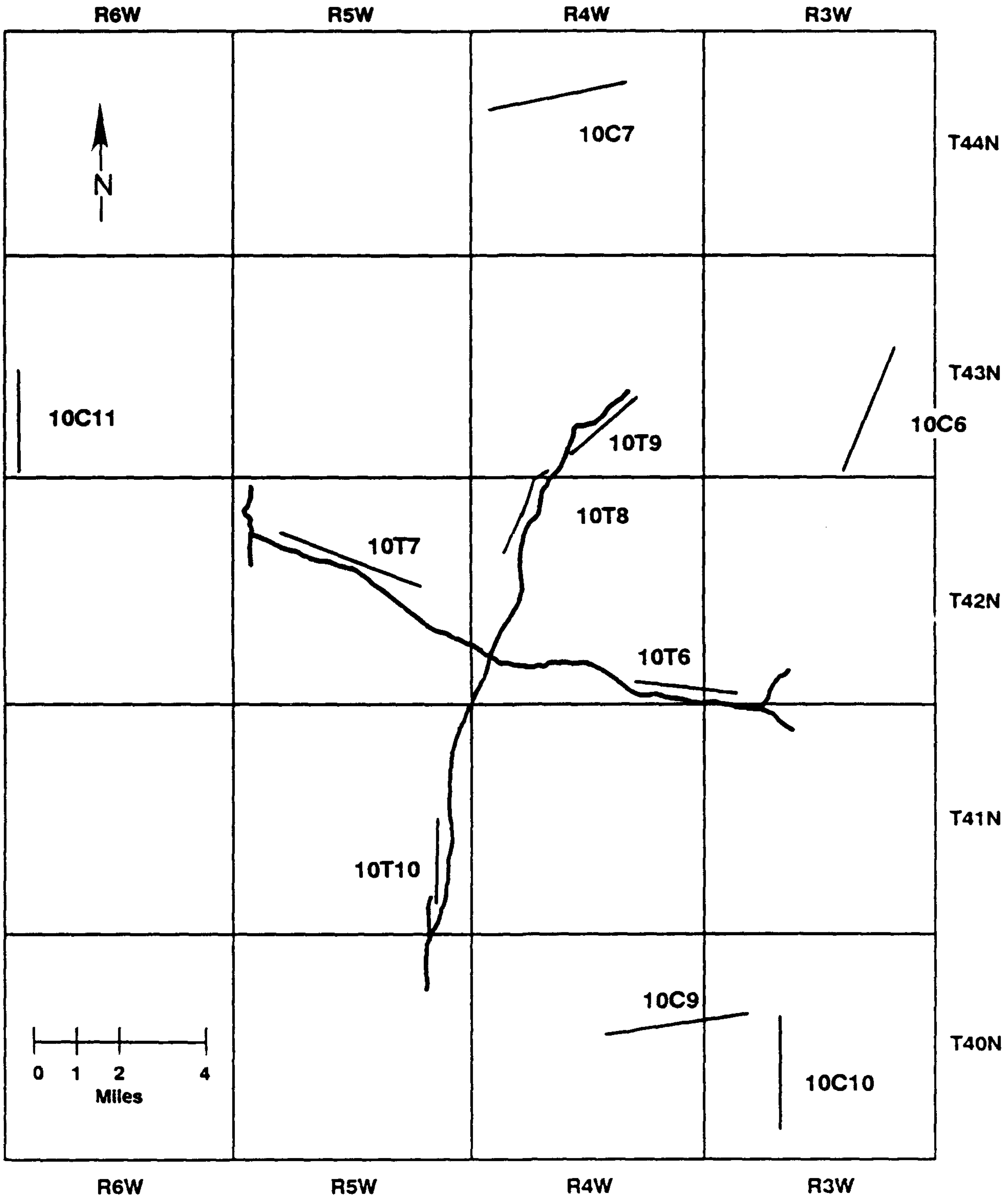
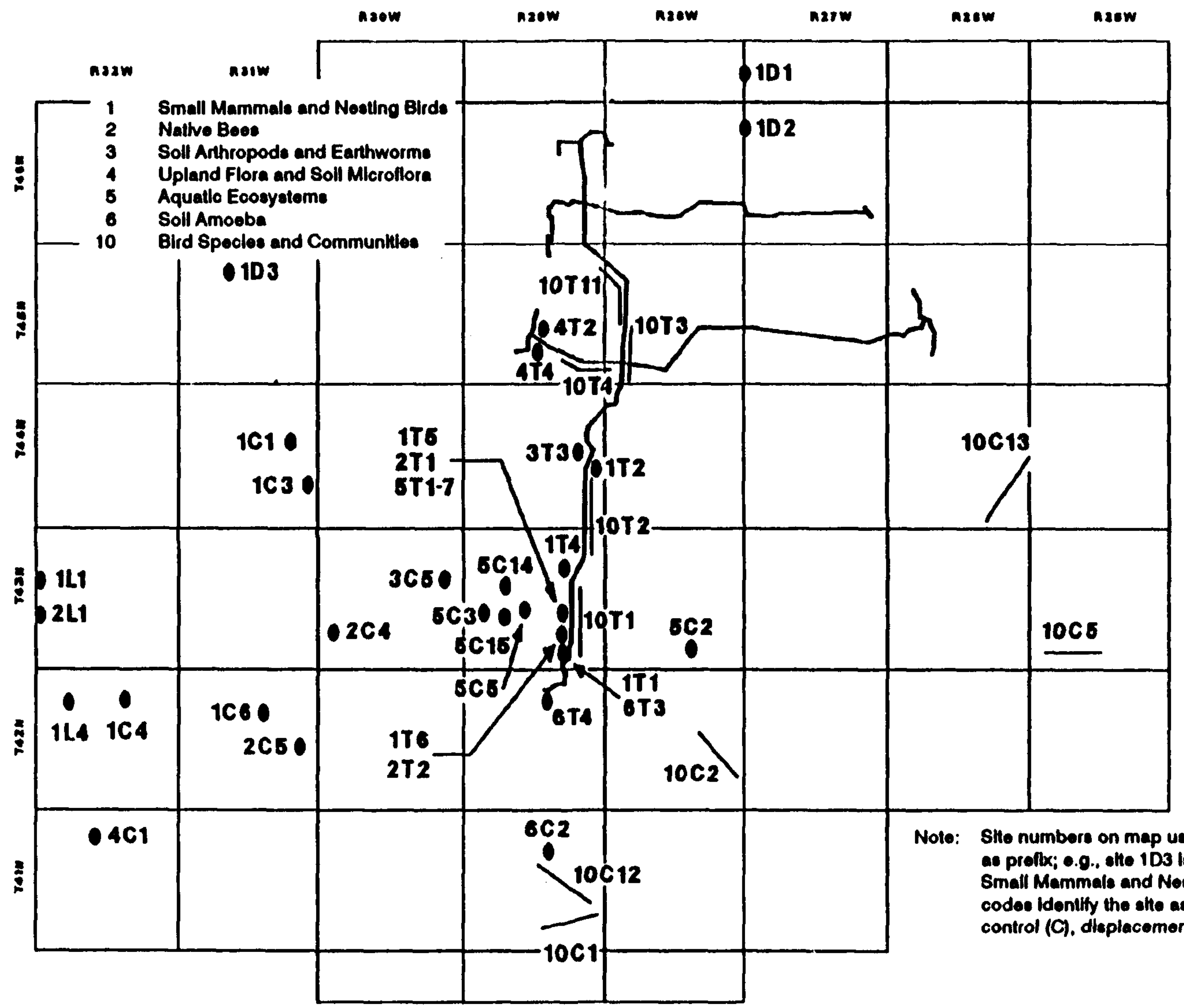


FIGURE 3. FIELD SITES FOR WISCONSIN BIRD SPECIES AND COMMUNITIES STUDIES.

60297/190



Note: Site numbers on map use study number as prefix; e.g., site 1D3 is part of Study 1, Small Mammals and Nesting Birds. Letter codes identify the site as treatment (T), control (C), displacement (D), or laboratory (L).

FIGURE 4. FIELD SITES FOR MICHIGAN ECOLOGY STUDIES.

3. ANNUAL EM FIELD MEASUREMENTS

3.1 Description of EM Fields of Interest

The three EM fields under investigation in this program are the magnetic field, longitudinal electric field, and transverse electric field.

A magnetic field is generated by current passing through a conductor. The ELF Communications System and power lines both produce consistent and predictable magnetic fields that are generally unaffected by the physical environment such as vegetation, soil, and nonmetallic structures. Magnetic fields are unchanged at such boundaries as air/earth or air/water. Thus, measurement techniques need not consider shielding, enhancements, or perturbations of the magnetic field from the local environment. This local uniformity of the magnetic field allows precise measurements over time, provided that the field source--in this case, the antenna current--remains constant.

The longitudinal electric field in the earth is measured as a difference in potential at the surface of the earth. The two sources of longitudinal electric field associated with the ELF Communications System are (1) that induced by the magnetic field and (2) that generated by the ground terminal currents. 60 Hz longitudinal electric fields produced by power lines are generated by the lines' magnetic fields and by unbalanced 60 Hz currents flowing in the earth. The uniformity of longitudinal electric fields is affected by the conductivity of soil and other factors such as large rocks, tree roots, and pools of water. Generally, the intensity of longitudinal electric fields is fairly uniform and measurements are repeatable when anomalies are avoided. Some year-to-year variations may occur because of changes in soil moisture content, which affect soil conductivity.

The transverse electric field in the air is generated as a result of the operating voltage of the ELF antenna with respect to ground or as a by-product of the longitudinal electric field. Power lines generate a transverse electric field in a similar manner. The operating voltage of the overhead antenna wire (or power line) with respect to the earth's surface sets up a vertical (transverse) electric field. This vertical field is limited to the ROW and other nearby cleared areas. Trees, vegetation, and other conductive objects act as shields.

A difference in potential between two grounded objects such as trees can be set up by the longitudinal electric field. This difference in potential in turn generates a horizontal electric field in the air. The horizontal and vertical fields are perturbed by vegetation, people, and instrumentation, all of which are more conductive than air. The perturbations of the field may take the form of an enhancing of the ambient field near objects or a shielding effect on the surroundings. This results in a high variability of the transverse electric field over a small area.

The transverse electric field is measured in open areas in an effort to obtain a typical unperturbed measurement.

3.2 EM Field Probes and Measurement Equipment

The magnetic flux density, transverse electric field intensity, and longitudinal electric field intensity are measured using directional field probes designed and calibrated by IITRI. Each of these probes, when placed in the existing electric or magnetic field, outputs a voltage proportional to the field intensity. The value of the applied field can be obtained by means of individual sets of calibration factors for each probe.

The magnetic field probe is composed of a multiturned coil of wire wound on a ferrite core and shunted by appropriately chosen resistors to obtain a flat frequency response. The probe generates an output voltage that is proportional to the magnetic flux density parallel to the axis of the core. This voltage is converted to the magnetic flux density by means of a calibration factor determined prior to each field outing. Two of these probes are shown in Figure 5.

The longitudinal electric field probe consists of three electrodes mounted on a fiberglass frame so as to form two orthogonal 1-m-spaced electrode pairs. The electrodes are pushed into the earth, and a switch connects a voltmeter across one pair of electrodes at a time. The voltage measured across each pair of electrodes is equal to the longitudinal electric field in the given direction. This probe is shown in Figure 6. Note that a compass and a cradle are mounted atop a 1-m vertical stalk that is hinged at the juncture of the probe legs. The compass aids in alignment of the probe legs prior to raising the stalk. The cradle is designed to hold the magnetic field probe in three orthogonal positions at a 1-m height and orient the probe precisely with the legs of the longitudinal electric field probe.

The transverse electric field probe consists of a spherical sensor/transmitter, a fiber-optic data link, and a receiver. The probe produces an output voltage proportional to the transverse electric field along the primary axis of the spherical sensor/transmitter. This voltage is converted to the electric field intensity by means of a calibration factor determined prior to each field outing. The calibration factor and probe operation are checked periodically using a portable electric field probe calibrator. This probe is shown in Figure 7. In very cold weather, a styrofoam-and-plastic shell is placed over the probe during measurements for protection and insulation.

IITRI has developed a computer-driven system for calibrating electric and magnetic field probes over their usable frequency range (see Figure 8). At the heart of the system are:

- a Hewlett-Packard 86B computer equipped with an IEEE 488 instrument interface bus
- a Hewlett-Packard 3421A data acquisition unit
- a Valhalla 2703 precision ac calibrator

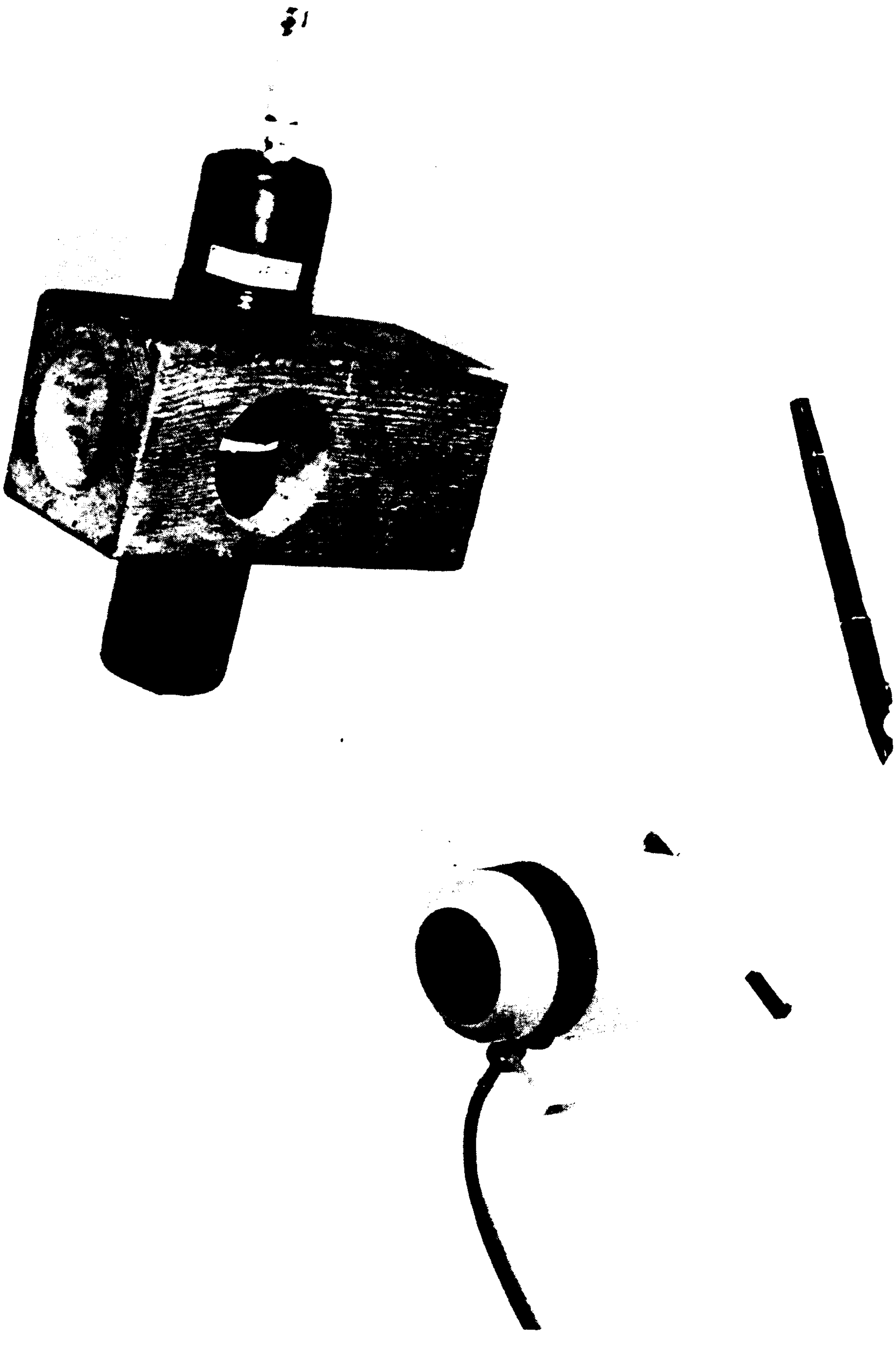


FIGURE 5. MAGNETIC FIELD PROBES.

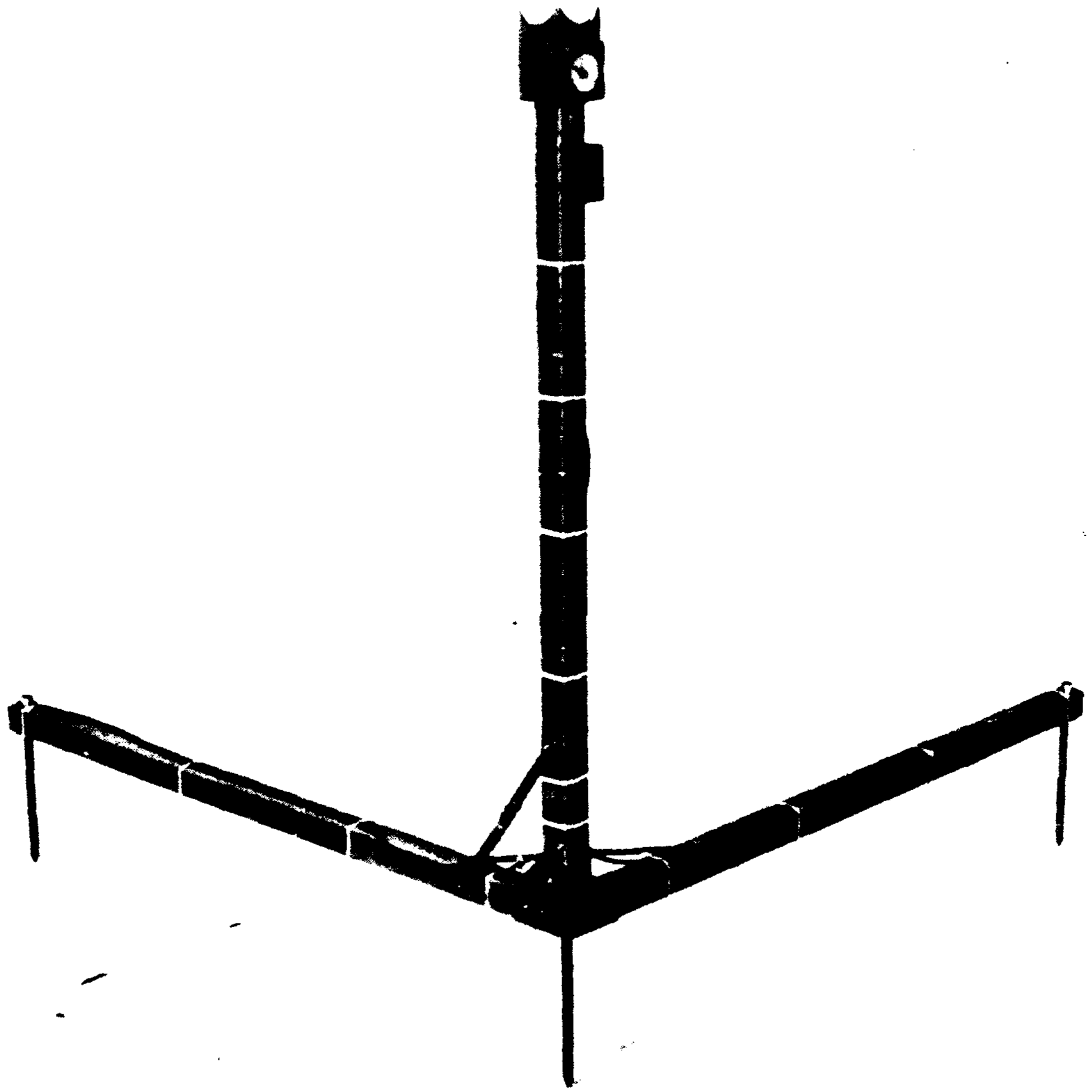


FIGURE 6. LONGITUDINAL ELECTRIC FIELD PROBE.

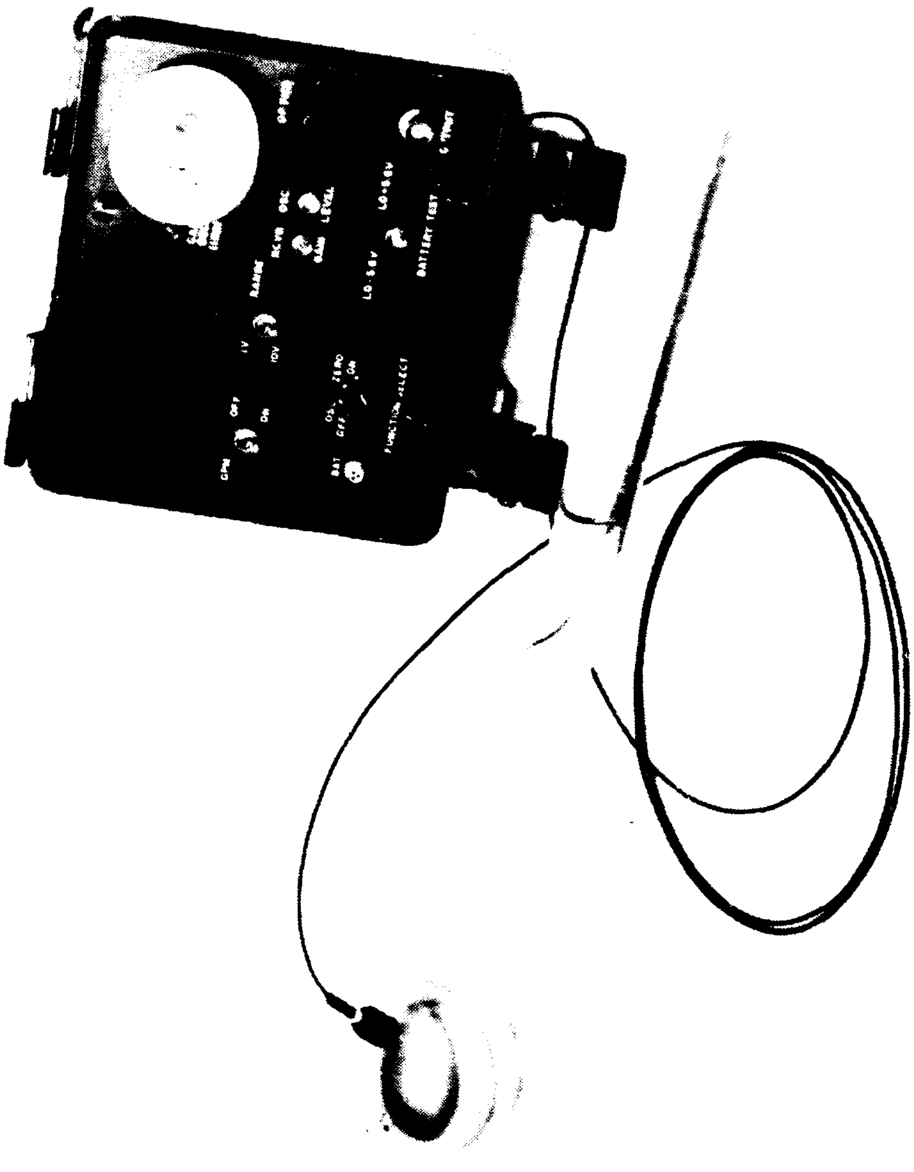


FIGURE 7. TRANSVERSE ELECTRIC FIELD PROBE.

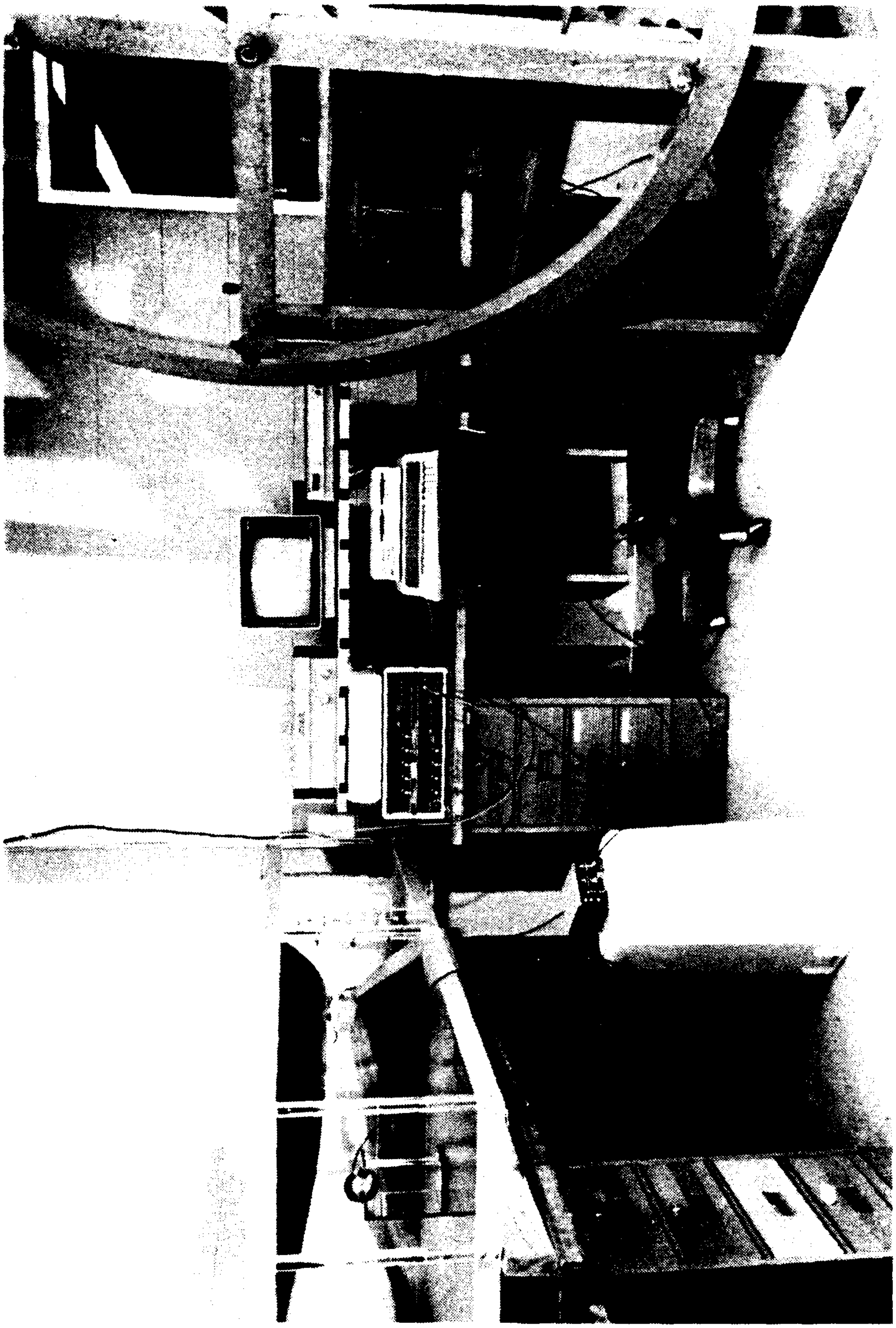


FIGURE 8. COMPUTER-DRIVEN ELECTRIC AND MAGNETIC FIELD PROBE CALIBRATION SYSTEM.

The calibration system generates a uniform electric field between a pair of 1-m-square, 1/3-m-spaced parallel plates with guard rings. A uniform magnetic field is generated over a large volume by a set of 1-m-radius Helmholtz coils. The calibration system produces a table of each probe's calibration factors and a plot of the probe's transfer function versus frequency. The transverse electric field probe and magnetic field probe are calibrated before and after each use, and a record is kept of all calibrations.

The electrical stability of the transverse electric field probe is better than ±5% over a one-year period. There is little difference in the calibration of this probe with or without its insulating styrofoam-and-plastic shell. Portable electric field calibration plates are used during field measurements so that the probe operation can be verified periodically. The electrical stability of the magnetic field probe is better than ±1% over a one-year period. This probe is constructed entirely of passive components, making routine calibration checks during field measurements unnecessary. The longitudinal electric field probe, which consists solely of a perpendicular pair of 1-m-spaced electrodes, requires no calibration. The electrical stability of this probe is excellent.

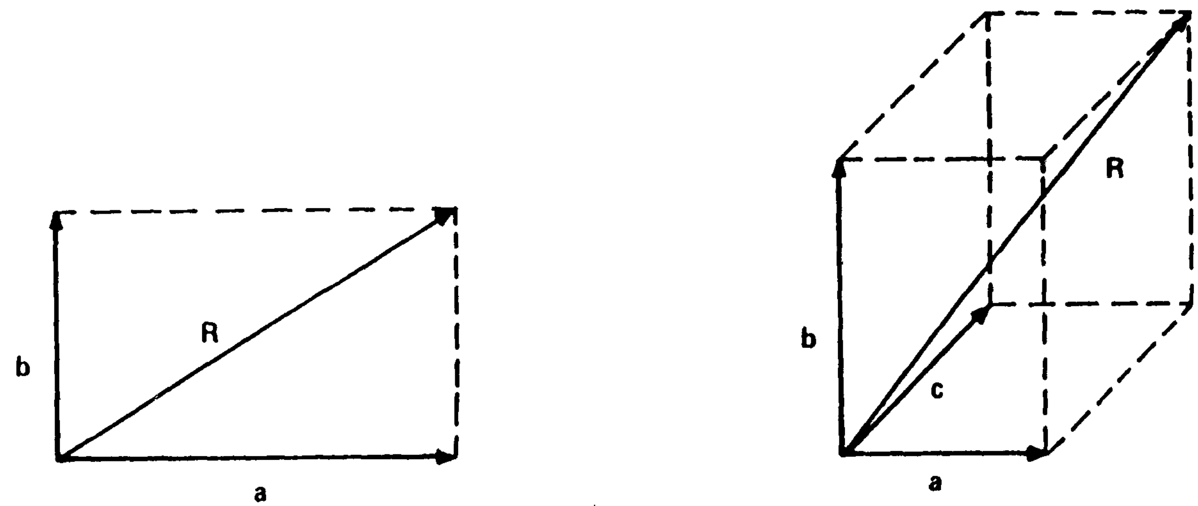
The meter used to measure the output voltages of the probes is a Hewlett-Packard 3581A signal wave analyzer. The HP 3581A functions as a frequency selective rms-calibrated voltmeter with factory modifications for battery and 1 Hz bandwidth operation. A 3 Hz bandwidth is used to measure 60 Hz and unmodulated ELF signals, but a wider bandwidth is needed to measure modulated ELF signals. Because the wider bandwidth will include 60 Hz signals produced by power lines, an IITRI-fabricated active notch filter is placed in series with the wave analyzer when the 60 Hz and ELF signals are of similar magnitudes in order to remove the 60 Hz signals and their harmonics.

3.3 EM Field Measurement Techniques and Protocols

3.3.1 Determining EM Field Magnitudes

The magnitude of an EM field vector is determined by the measurement of its orthogonal components. This requires measurements with the field probe oriented along three orthogonal axes. For simplicity and repeatability, the axes chosen are aligned in the north-south, the east-west, and the vertical directions. The longitudinal electric field intensity (electric field measured in the earth) has no vertical component; therefore, only the north-south and east-west components are measured. In the case of the transverse electric field and magnetic flux density, all three orthogonal field components are measured. The orthogonal measurements are then used to compute a vector sum or maximum.

A geometric presentation of the measurement and summation of orthogonal components is shown in Figure 9. The figure presents the two-dimensional longitudinal electric field geometry



$$R = \sqrt{a^2 + b^2}$$

$$R = \sqrt{a^2 + b^2 + c^2}$$

FIGURE 9. GEOMETRIC PRESENTATION OF THE VECTOR SUM OF ORTHOGONAL MEASUREMENT COMPONENTS.

and the three-dimensional magnetic field and transverse electric field geometry. The resultant, R, in each case is the vector sum of the individual orthogonal components and is the value reported in data tables.

One disadvantage of the orthogonal components method is that it yields the correct field maximum only when a single field source is present or dominates. Fortunately, this is generally the case. When more than one field source is present, the computed vector sum will be conservative; that is, it will be greater than or equal to the actual maximum. Measurements have been made in Wisconsin at those sites where a single antenna does not dominate to determine correction factors for calculating actual field magnitudes. These correction factors, listed in Appendix I, are site specific, and have not yet been determined for measurement points in Michigan that are near both antennas.

3.3.2 Measurement Conditions--Wisconsin

The NRTF-Clam Lake was built in the late 1960s to be used as a test facility for ELF communications.

Before 1985, the NRTF-Clam Lake operated intermittently at numerous frequency, modulation, and intensity conditions with either the NS, the EW, or both antennas being powered. During this period, the NRTF-Clam Lake was generally under local control, and specific conditions of antenna current, modulation, frequency, and phase angle could be requested for measurements and testing.

In 1985, the NRTF-Clam Lake was upgraded to a fully operational system with the installation of new transmitters early in the year. The transmitters required testing in mid-year, which allowed only limited manipulation of antenna conditions. This was followed by full-time transmission during the fourth quarter, with no control over antenna conditions. The NRTF-Clam Lake has continued transmitting full-time since then.

With the loss of antenna control brought about by full-time operation and modulated signal transmission, a new measurement protocol was developed and employed for 1986 through 1988. In 1989, special testing performed during the annual EM measurement survey in Wisconsin allowed for a modified, more comprehensive measurement protocol.

Table 1 shows the predominant operating conditions under which measurements were made in Wisconsin. In all cases, the orthogonal components of the magnetic flux density and of the transverse and longitudinal electric fields were measured, and a vector sum magnitude was computed for each EM field. Unless otherwise stated, this vector sum magnitude is the value reported in all measurement documentation. For the three bird species and communities study sites where phasing data had been obtained, the longitudinal electric field vector sum magnitudes, measured during operation of both antennas, were multiplied by the correction factor from Appendix I to obtain the

TABLE 1. ANTENNA OPERATING CONDITIONS DURING 76 Hz EM FIELD MEASUREMENTS IN WISCONSIN

Antenna Condition	Pre-1985	1985-1988	1989
Antenna	NS, EW	B*	NS, EW, B*
Antenna Current (amperes)	150 or 300	300	300
Frequency (Hz)	76	76	44, 76
Modulation	CW	MSK	CW, MSK
Phase	N/A	-75°	-75°, 105°

*B = Both antennas simultaneously.

actual EM field magnitude. This correction factor is not applied, however, to measurements made during operation of a single antenna.

The following subsections describe the pre-1985 protocol, the protocol used from 1985 through 1988, and the 1989 protocol used in Wisconsin.

3.3.2.1 Pre-1985 Conditions. Prior to June 1985, the EM measurement protocol in Wisconsin consisted of making orthogonal sets of measurements of the transverse electric field, longitudinal electric field, and magnetic flux density at each measurement point as follows:

- Ambient 60 Hz EM fields were measured with both antennas off.
- 76 Hz EM fields from the NS antenna were measured with the EW antenna off.
- 76 Hz EM fields from the EW antenna were measured with the NS antenna off.

All measurements were made using a narrow bandwidth meter setting to discriminate the frequency of interest. When necessary, the 76 Hz EM fields at the NRTF-Clam Lake measured at lower currents were extrapolated to 300 amperes (full power).

3.3.2.2 1985-1988 Conditions. In 1985, the NRTF-Clam Lake measurement protocol was modified to accommodate measurements during continuous, phased operation of the two antennas. That protocol was as follows:

- 76 Hz fields were measured with both antennas on, using a meter bandwidth setting of 30 Hz to accommodate the wider frequency spectrum of the modulated signal.
- At control and/or other sites where the 60 Hz ambient EM fields were comparable to the ELF fields, an IITRI-fabricated active notch filter was used to eliminate the 60 Hz signal from the field measurement.
- The 60 Hz ambient EM fields were unmeasurable unless the ELF transmitter could be turned off (unlikely during fleet transmissions), or unless the ambient 60 Hz levels were higher than the ELF-signal-generated "noise" at the same frequency. This latter scenario occurred only at certain control sites. When 60 Hz EM fields were measured, a narrow bandwidth meter setting (1 Hz or 3 Hz) was used.

This protocol allowed for direct comparisons between pre- and post-1985 data for all but three bird species and communities study sites. These three sites--10T6-2, 10T8-4, and 10T10-1--are near enough to both WTF antennas that their EM fields vary with the phasing of the antennas. Appendix I contains tables of conversion factors for these sites that allow comparisons of EM field measurements made in any year at any antenna phasing.

3.3.2.3 1989 Conditions. A special test schedule in effect at the NRTF-Clam Lake during the 1989 annual EM survey allowed measurement of the 60 Hz ambient fields for the first time since 1985. It also allowed measurements to be taken with the NRTF-Clam Lake operating both at its secondary frequency of 44 Hz and at its primary frequency of 76 Hz. The 1989 protocol was as follows:

- 44 Hz and 76 Hz EM fields were measured with both antennas on, or during operation of only the dominant antenna at some treatment sites. A 3 Hz meter bandwidth was used for unmodulated signal transmission; a 30 Hz bandwidth was used for modulated operation.
- 60 Hz EM fields were measured with both antennas off, or with unmodulated signal transmission. A 3 Hz bandwidth was used.

3.3.3 Measurement Conditions--Michigan

Construction of the NRTF-Republic began in 1984 and continued through 1985. During this period, the NRTF-Republic was not capable of generating ELF EM fields. Construction of the NRTF-Republic was completed in early 1986, and intermittent operation began at low power levels of 4 to 10 amperes of antenna current. Only one antenna or antenna element (the NS antenna or the NEW or SEW antenna element) was operated at any one time during 1986.

The NRTF-Republic operated intermittently at a 15 ampere antenna current in 1987 and at 15 and 75 ampere antenna currents in 1988. However, from 1987 onward the NEW and SEW antenna elements were connected in parallel and operated as one antenna, hereafter referred to as the EW antenna. In 1987 and 1988, only one antenna was operated at any one time.

In 1989, the NRTF-Republic operated both antennas (NS and EW) simultaneously, at a full-power current level of 150 amperes. Both modulated and unmodulated (continuous wave) signals were employed.

Table 2 summarizes the predominant operating conditions under which measurements have been made in Michigan. In all cases, the orthogonal components of the magnetic flux density and of the transverse and longitudinal electric fields were measured, and a vector sum magnitude was computed for each EM field. Unless otherwise stated, this vector sum magnitude is the value reported in all measurement documentation.

TABLE 2. ANTENNA OPERATING CONDITIONS DURING 76 Hz EM FIELD MEASUREMENTS IN MICHIGAN

Antenna Condition	1986	1987	1988	1989
Antenna or Antenna Element	NS NEW SEW	NS EW	NS EW	B*
Antenna Current (amperes)	NS --4 NEW--6 SEW--6	NS--15 EW--15	NS--75 EW--75	B*-150
Frequency (Hz)	76	76	76	76
Modulation	CW	CW	CW	CW, MSK
Phase	N/A	N/A	N/A	86°
Status of Non-Driven Antenna Element(s) at Transmitter	Grounded	Connected to transmitter	Connected to transmitter	N/A

*B = Both antennas simultaneously.

The following subsections describe the 1986-1989 measurement protocols used in Michigan.

3.3.3.1 1986 Conditions. The 1986 EM measurement protocol for Michigan was as follows:

- Ambient 60 Hz EM fields were measured with all three antennas or antenna elements (NS, NEW, and SEW) off.
- 76 Hz EM fields from the NS antenna were measured with both EW antenna elements off.
- 76 Hz EM fields from the NEW antenna element were measured with the other antennas or antenna elements off.
- 76 Hz EM fields from the SEW antenna element were measured with the other antennas or antenna elements off.

All measurements were made using a meter bandwidth setting of 3 Hz to discriminate the frequency of interest.

3.3.3.2 1987, 1988 Conditions. In 1987 and 1988, the EM measurement protocol for Michigan changed only slightly from the 1986 protocol to account for the new operating configuration. That revised protocol was as follows:

- Ambient 60 Hz EM fields were measured with the NS and EW antennas off.
- 76 Hz EM fields from the NS antenna were measured with the EW antenna off.
- 76 Hz EM fields from the EW antenna were measured with the NS antenna off.

All measurements were made using a meter bandwidth setting of 3 Hz to discriminate the frequency of interest.

3.3.3.3 1989 Conditions. In 1989, the EM measurement protocol for Michigan changed slightly because the NS and EW antennas operated simultaneously during all measurements. Modulated signal operation also necessitated protocol modifications. The 1989 protocol was as follows:

- Ambient 60 Hz EM fields at control study sites were measured under any antenna operating conditions.
- Ambient 60 Hz EM fields at test study sites were measured either with the antennas off or operating with an unmodulated signal. Measurements of 60 Hz fields at test sites could not be made under modulated signal operation.
- 76 Hz ELF EM fields were measured with both antennas on and with either a modulated or unmodulated signal.

Unmodulated ELF and 60 Hz EM field measurements were taken using a meter bandwidth setting of either 1 Hz or 3 Hz to discriminate the frequency of interest. Modulated ELF signals were measured using a meter bandwidth setting of 30 Hz.

3.3.4 Selection of Measurement Points

Measurement points at study sites were selected to define the spatial variation of the 76 Hz EM fields over each site. This was done on the basis of the size and shape of a site and its location relative to the antenna elements, as described below.

Control sites, all of which are several miles from the nearest antenna element, are expected to have minimal EM field gradients. At small control sites, a single measurement point was deemed sufficient to characterize the EM fields. Intermediate-size control sites were measured at the points nearest to and farthest from the antenna grid. Large control sites were measured at several more points in order to accurately define the EM field gradients across them.

EM field gradients across treatment sites are large for all but the smallest of sites. It was generally necessary to make multiple measurements at all treatment sites. The selection of measurement points for the treatment sites was based on one of four strategies dictated by the nature of the site. For sites comprised of long, narrow transects parallel to the antenna (e.g., the bird species and communities studies), measurements typically were taken at the ends of the transect and often at intermediate points along the transect. For sites of very restricted area (e.g., the aquatic ecosystems studies), only one measurement was made at each experiment location. The final two measurement strategies were applied at treatment sites covering a large area. For those sites arranged with well defined, grid-like borders, measurements were made at the borders or corners of the plots such that the measurements encompassed the study area. For those sites

without distinct borders, measurements were made along a transect perpendicular to the antenna, typically at 25-m intervals.

This measurement point selection technique allows the investigators to estimate the EM field intensity at any point of interest within a study plot. Such estimates can be made based on the fact that the EM fields vary greatly with distance from the antenna but show little variation along a path parallel to it. Therefore, given the distance of a point of interest from the antenna, the EM fields can be estimated by interpolation between measured values at greater and lesser distances from the antenna. Because the EM fields vary little along a path parallel to the antenna, the point of interest and measured points do not need to be at the same lateral position along the length of the antenna. The EM field can be estimated by linear interpolation between the two measured points. The accuracy of the interpolation can be improved by plotting the EM field gradients as a function of distance from the antenna, as was done for all transects at the nesting birds study sites and the upland flora and soil microflora study sites. These plots appear in Appendixes A and D.

3.4 Summary of Measurement Data

The annual EM field measurements in Wisconsin were conducted by IITRI field crews during the weeks of 14 to 18 and 21 to 25 August 1989. Measurements in Michigan were conducted on 21 February, 10 May, during the weeks of 11 to 15 and 18 to 22 September, and on 11 and 12 October 1989. All active sites were measured during these periods.

Table 3 presents a summary of the number of sites and measurement points examined during 1989. As shown, a total of 218 measurement points were needed to characterize 62 sites. The number of measurement locations per site was determined by plot size, the presence of known or anticipated EM field gradients, and the information needed by the study investigators for statistical analyses.

3.4.1 Wisconsin Measurement Data

The data taken during the 1989 EM measurements at the bird species and communities study transects in Wisconsin appear in Appendix G. There are ELF data tables and a 60 Hz data table for each of the three fields characterized (transverse electric field, longitudinal electric field, and magnetic flux density). There is also a table documenting the 76 Hz magnetic flux density and electric field intensity profiles along a line perpendicular to transect 10T8 and a table documenting field variability at regular intervals along all the treatment transects and one control transect. These measurements are discussed in Section 4.4.3 of this report.

TABLE 3. SUMMARY OF 1989 EM FIELD MEASUREMENTS

Study	Number of Measurement Sites: Pre-Existing, Still in Use	New, 1989	Total	Number of Measurement Points: Pre-Existing, Still in Use	New, 1989	Total
Small Mammals and Nesting Birds	14	0	14	64	5	69
Native Bees	5	1	6	18	4	22
Soil Arthropods and Earthworms	2	0	2	8	0	8
Upland Flora and Soil Microflora	6	0	6	32	13	45
Aquatic Ecosystems	10	1	11	17	2	19
Soil Amoebae	3	0	3	9	0	9
Bird Species and Communities						
Michigan	10	0	10	24	0	24
Wisconsin	10	0	10	22	0	22
Total	**60**	**2**	**62**	**194**	**24**	**218**

The ELF data tables are the first to appear in Appendix G. These tables present 76 Hz data for 1984-1989 and 44 Hz data for 1989. The data for 1984 and some points in 1985 were measured during individual operation of the NS and EW antennas and are presented as such in the tables. Other data for 1985-1989 were taken during operation of both antennas, with noted exceptions in 1989, and appear in columns labeled "B."

The 76 Hz data is relatively consistent from 1984-1989 for all measurement points in Wisconsin. Expected variations in this data are greatest for the transverse and longitudinal electric fields because of their sensitivity to perturbations in measurement conditions such as vegetation growth and soil moisture changes. The magnetic flux density is unaffected by these perturbations, and therefore shows more stability from year to year.

The longitudinal electric field is directly proportional to frequency (see Section 4.5). This phenomenon is evidenced by the 44 Hz longitudinal electric field measurements made in 1989, which are proportionally lower than the 76 Hz measurements of these fields. The transverse electric field is largely a by-product of the longitudinal electric field at most measurement points. Therefore, 44 Hz transverse electric fields are typically lower than the 76 Hz measurements of these

fields even though the transverse electric field is not directly dependent on frequency. The magnetic flux density is neither frequency-dependent nor a by-product of a frequency-dependent field. This is exemplified by the consistency between the 44 Hz and 76 Hz magnetic flux densities.

The 60 Hz data table contains 60 Hz EM field intensities for all three fields measured in 1984, 1985, and 1989. The 60 Hz data is consistent in these three years for all measurement points in Wisconsin.

The EM field profile data is discussed in Section 4.4.3 of this report. Measurement points are identified in columns listing the study transect number and investigator's sub-transect designation.

3.4.2 Michigan Measurement Data

The data taken during the 1989 EM measurements in Michigan appear in Appendixes A through G, each of which contains six data tables. There are a 60 Hz data table and a 76 Hz data table for each of the three fields characterized (transverse electric field, longitudinal electric field, and magnetic flux density). In addition, separate tables documenting measurements taken at the small mammals and nesting birds laboratory appear in Appendix A. These laboratory measurements are discussed in Section 4.1.1.

In each appendix, the tables of 60 Hz data appear first. Each table contains a separate column of data for each year from 1983 through 1989. A footnote for each column describes the physical status of the ELF antenna during the 60 Hz measurements for that year. The physical status of the ELF antenna has a significant impact on the 60 Hz EM fields measured at test sites because it affects the degree of coupling to the antenna of 60 Hz EM fields generated by nearby power lines. This phenomenon is explained in Section 3.4.3.

Following the 60 Hz data tables are tables containing 76 Hz EM field intensities measured in 1986 through 1989. The 76 Hz EM field intensity data were taken at several different antenna operating currents, ranging from 4 amperes in 1986 to the full operating power of 150 amperes for the first time in 1989. Specific operating currents are given in the column headings of the data tables. EM field intensity values, as shown in the data tables, have increased proportionally to the antenna operating current from 1986 through 1989.

Aside from variations in the EM field intensities attributable to the antenna operating current, the 76 Hz EM data are relatively consistent from 1986 through 1989 for all measurement points in Michigan. Expected variations due to perturbations in measurement conditions such as vegetation growth and soil moisture changes were seen in Michigan EM field measurement data, just as in Wisconsin.

3.4.3 Coupling of 60 Hz Fields

The 60 Hz data for Michigan studies in Appendixes A through G show that there were significant yearly fluctuations of the 60 Hz EM fields from 1983 through 1989. The primary factors in these fluctuations were:

- completion of antenna installations in 1986
- parallel connection of the two EW antenna elements in 1987
- differences in antenna-power amplifier connections between 1986 and 1987
- changes in power line loads
- changes in earth conductivity

The first three factors apply only to treatment sites; the last two apply to both treatment and control sites.

The 60 Hz EM fields at the treatment sites are strongly influenced by the presence of the ELF antenna elements. This is because EM fields generated by 60 Hz power lines couple to the conducting loop formed by the ELF antenna, its ground terminals, and the earth. This coupling results in a 60 Hz current flow on the antenna wires that in turn sets up new 60 Hz EM fields nearby. The 60 Hz EM fields generated by the two sources (power lines and antenna) may interact at test measurement sites and elsewhere. The general observation has been that the longitudinal electric fields sourced by the power lines and antenna partially cancel each other. The relative magnitude of the resulting EM field is dependent on the intensities of the EM fields generated by the two sources. The magnetic fields from power lines fall off more rapidly than the longitudinal electric fields, and they do not appear to significantly interact with the 60 Hz magnetic fields from the antenna. The result is that 60 Hz magnetic fields near the antenna are greater in magnitude than those measured prior to antenna construction.

The coupling of ambient 60 Hz fields to the ELF antenna was first observed in 1986, coincident with the completion of antenna construction in Michigan. This coupling will continue as long as the ELF antenna and power lines are present. Year-to-year differences in the treatment site 60 Hz EM fields are likely due to changes in coupling to the antenna elements resulting from changes in antenna configuration and to changes in 60 Hz power line loads. The antenna configuration changes were the connection of the two EW antenna elements in parallel beginning in 1987 and differences in the antenna connections to the power amplifiers between 1986 and 1987 in the antenna "off" mode, the antenna condition when 60 Hz measurements are made.

In 1988, 60 Hz coupling to the NS antenna appeared to have increased substantially. This correlates with large load increases on a transmission line that parallels the NS antenna element about four miles to the west. The purchase of the Presque Isle power plant by Wisconsin Electric

Power Company in January 1988 and its subsequent operation as a major producer of electrical energy in the region suggests that this line will remain heavily loaded.

Variations in the 60 Hz EM fields at control sites are not related to the location of the ELF antenna or its configuration. 60 Hz variations here are most likely the result of varying power line currents and temporal changes in earth conductivity. These same factors also influence the 60 Hz EM fields at treatment sites, but not necessarily to the same extent.

4. ENGINEERING SUPPORT ACTIVITIES

4.1 Laboratory Measurements

Some study species are subjected to EM exposures other than those at the established study sites. The experimental protocols for the studies of small mammals and nesting birds, native bees, and soil amoebae, for example, are unique in that they require the study species to be removed from the study sites to undergo laboratory measurements, after which they are returned to the study sites. The EM environment at these laboratories should match the criteria established for control sites such that possible differences between treatment and control subjects attributable to 76 Hz EM field exposure are not masked by unwanted EM field exposures at the laboratories.

Measurements made at the laboratories of the small mammals and nesting birds and native bees studies in past years showed that the 60 Hz EM fields there were on the same order of magnitude as 76 Hz EM fields at the test sites. Efforts were made to reduce these exposures (1) by asking investigators to limit the amount of time study biota spend at the laboratory, and (2) by reducing the EM field intensities at the laboratory. A discussion of these efforts follows. Similar 60 Hz EM field characterizations have not yet been performed at the soil amoeba studies laboratory. IITRI plans to make such measurements in 1990.

4.1.1 Small Mammals and Nesting Birds Laboratory Measurements

It is not known if ELF EM fields affect vertebrate metabolism, nor which aspects of exposure (i.e., intensity, duration, or both) could be important. The unmitigated 60 Hz EM field intensities at the small mammals and nesting birds laboratory in Crystal Falls are high relative to both 76 Hz and 60 Hz EM intensities at the study sites. Nevertheless, there exists a need to move animals from study sites to the laboratory for testing. The 60 Hz fields at the laboratory are considered as possible contaminants, and measures that reduce both the duration and intensity of exposure of the study animals to 60 Hz EM fields at the laboratory have been recommended and implemented.

In order to reduce the amount of time that animals spend at the laboratory site, a remote holding facility was set up in 1987-88 for the animals to reside in prior to laboratory testing. A holding facility is required because the tests are conducted in winter, and daily access to the study sites would be extremely difficult and time consuming. The EM field values at the remote holding facility are similar to those at the control sit s.

The 60 Hz magnetic and air electric field values measured in the laboratory in early 1989 were nominally on the same order of magnitude as the 76 Hz field values at the treatment sites during 150 ampere operation. Prior to 1990 metabolic studies, IITRI acted to reduce the laboratory magnetic fields at the cooling bath, where they were the highest, by designing, fabricating, and

installing magnetic shielding for the cans used to hold animals in the bath during metabolic testing and for the motors contained in the bath. IITRI also performed mitigation tests and recommended methods of lowering the air electric fields throughout the laboratory.

The approach taken for magnetic shielding was to use a metal with high magnetic permeability (Mumetal) to redirect or "duct" magnetic flux away from the cans. Thin Mumetal (0.025 in.) was wrapped snugly around the sides of each can, and Mumetal discs were attached to the top and bottom. In order to maintain the thermal transfer properties of the cans, an alumina-impregnated material (0.065 in. uncompressed) was sandwiched between the Mumetal shields and the steel cans. This heat-transfer material filled the air gap between the Mumetal and the cans, which otherwise might function as a thermal insulator. A shielded can was only slightly larger than its unshielded counterpart, and only minor changes were necessary in the fixtures used to position the cans in the bath.

The principal sources of the magnetic fields in the bath were a pump motor and a compressor motor. Magnetic fields from these sources were redirected using three Mumetal shields.

Motor and can shields together reduced the magnetic field exposures inside the cans by 30 to 68 times at the two locations used for testing, thus lowering the magnetic flux densities to 0.077 mG and 0.081 mG. These reduced 60 Hz magnetic fields are 20 to 500 times lower than 76 Hz magnetic fields and roughly equivalent to 60 Hz magnetic fields at treatment sites.

The air electric field intensities in the laboratory were reduced by either shielding and/or grounding identified field sources. Field mitigation techniques recommended by IITRI were as follows:

- Put overhead fluorescent light fixtures on a grounded circuit with wiring in metal conduit.
- Shield the fluorescent tubes with 0.25-in.-mesh hardware cloth, and ground the mesh to the light fixture.
- Shield the desk lamp bulb with 0.25-in.-mesh hardware cloth, and ground the lamp frame.
- Ground large metallic objects (desks and locker) in the laboratory that have a non-zero potential and hence set up an air electric field.
- Install and ground a 0.25-in.-mesh hardware cloth shield beneath and behind the animal holding cages in the laboratory. Install clip leads to directly ground the animal cage assemblies.
- Install a ground rod and clip leads to ground the animal cages located at the short-term holding area on the side of the shed outside the laboratory.

These recommendations were implemented by the study investigators. They had the effect of reducing the laboratory air electric fields by 4.5 to 20 times. The 60 Hz air electric fields in

the laboratory are now on the same order of magnitude as the 76 Hz air electric fields and 1 to 500 times higher than the 60 Hz electric fields at treatment sites. Measurements made at the small mammals and nesting birds laboratory are detailed in Appendix A.

4.1.2 Native Bees Laboratory Measurements

Measurements of EM fields at the native bees laboratory in Crystal Falls, first made in 1988, showed that the 60 Hz fields in the laboratory were up to 1000X the value of 60 Hz fields at the study sites, and equal to or greater than the 76 Hz exposures at the study sites. IITRI recommended that these exposures be reduced by limiting the amount of time that the bee nest blocks are kept at the laboratory. This was accomplished by sharing the remote holding facility used by the small mammals and nesting birds investigators for holding the bees prior to laboratory testing. As a further step, EM field exposures were reduced by moving the laboratory testing location from the basement to the second floor, where EM field intensities are lower.

EM field intensities were remeasured in the laboratory in 1989. The 60 Hz air electric fields in the second-floor testing area and on the porch, where nest blocks are held prior to examination, were still typically greater than 76 Hz air electric field values at treatment sites during full-power operation of the antenna. IITRI fabricated wire-mesh cages to shield the work and holding areas from the 60 Hz air electric fields experienced at these two locations. The shielded cages will be installed prior to 1990 laboratory testing, and EM field measurements will be made to verify their effectiveness.

The 60 Hz magnetic fields at the native bees laboratory are typically at least a factor of 10 lower than the 76 Hz magnetic fields at the test sites. Shielding of the magnetic fields is not being considered for this laboratory. EM measurements at the native bees laboratory are detailed in Appendix B.

4.2 Soil Amoeba Culture Chambers

The soil amoeba studies use sealed culture cells that isolate the study organisms from the surrounding soil. This *in vitro* procedure allows close monitoring of biotic end points without contamination from other soil organisms and bacteria. The culture cells are buried in the earth at shallow depths at treatment and control sites, thus exposing the cultures of soil amoebae to the earth's ambient temperature. It is also desirable to expose the amoebae to the same EM environment that they would encounter if living in the soil. Ideally, this would be accomplished simply by connecting electrodes in the culture cell directly to the earth, so that the electric voltages and currents present in the earth could be applied to, and flow through, the culture medium in the cell. However, the electric field exposure in the culture cells is complicated by a mismatch between the conductivity of the soil and that of the culture growth medium. Therefore, external control

circuitry must be used to regulate the drive voltages that are applied to the culture cell electrodes. Collector electrodes in the earth supply the raw drive voltages.

Two basic culture cell drive control circuits were developed: one for matching electric field exposure in the culture cell to that of the earth, and the other for matching current density exposure. Drive control circuits and protocols explaining their use are detailed in Appendix J. Magnetic flux is not perturbed by the culture cells.

Culture cells and control apparatus were installed at the soil amoeba study sites in 1987, 1988, and 1989. Control voltages V_{CL} and V_R and open circuit voltage V_{OC} were measured according to the protocol outlined in Appendix J. Culture cell electric field (E_{CL}) and current density (J_{CL}) are calculated from exposure control measurements as follows:

$$E_{CL} = \frac{V_{CL}\ (\text{volts})}{0.113\ \text{m}} \quad (\text{V/m}) \tag{5}$$

$$J_{CL} = \frac{V_R\ (\text{volts})}{R\ (\text{ohms})\ 1.42 \times 10^{-4}\ \text{m}^2} \quad (\text{A/m}^2) \tag{6}$$

where 0.113 m is the measured distance between culture cell electrodes, and 1.42×10^{-4} m^2 is the cross-sectional area of the culture cell growth medium assuming a cell half full of medium.

IITRI designed and installed microprocessor-controlled data loggers at all soil amoeba study sites in 1988. Figure 10 shows a data logger beside a portable personal computer that is used to initiate logger operation and to offload data at the end of each measurement period. In 1988, data loggers measured the voltage and current of the culture cells, the temperatures within the partially buried data logger enclosures, and the earth electric field at each site. The data loggers remained at the study sites after the culture cells were removed for the season in late September 1988, and were used to continue monitoring the earth electric field at the sites.

In 1989, the data loggers were removed from the field study sites for three months in the spring for laboratory testing and hardware upgrades. Upgrades included the addition of soil temperature probes and an increase in the battery capacity to extend the operating period. A 60 Hz notch filter was also added to the control site data logger to allow discrimination between the 76 Hz and 60 Hz fields, which are of comparable intensities at this location.

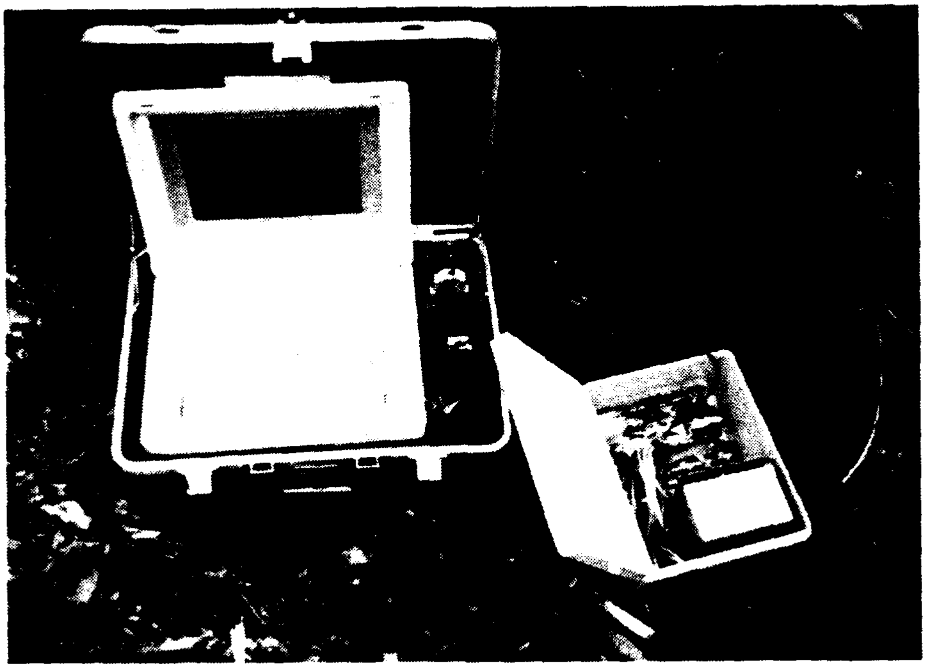


FIGURE 10. MICROPROCESSOR-CONTROLLED FIELD DATA LOGGER (RIGHT) WITH A PORTABLE PERSONAL COMPUTER.

Data logger measurement protocols were also modified in 1989 to support the new hardware and the anticipated antenna operating conditions. Protocols used in 1988 and 1989 are summarized in Appendix F.

Samples of data collected by data loggers during the 1988 field season are presented in Figures 11 and 12. Figure 11 shows the culture cell electric fields for matched electric field cells based on hourly measurements at the antenna and ground study sites. The electric fields in this figure were calculated using Equation 5 and data logger measurements of the cell voltage (V_{CL}). The data presented in Figure 12 are calculated current densities for matched current density cells based on hourly measurements at the antenna and ground study sites. These values were calculated using Equation 6 and data logger measurements of the voltage across the current limiting resistor (V_R).

The data presented in Figures 11 and 12 were measured while the NS antenna operated with a 75 ampere current and either a 44 Hz or 76 Hz frequency. Gaps in the data sequence correspond to periods when the antenna was not operated. Variability in the data presented in these two figures is due to several factors. First, the electric field in the earth, which is the driving voltage for both the matched electric field and matched current density cells, is frequency dependent. This frequency dependence is more prevalent at the antenna site than at the ground site (see Section 4.5.1); hence, data measured at 44 Hz and 76 Hz operating frequencies are more distinguishable in the antenna site plots. Other factors that affect the EM fields in the test cells are soil conductivity and the conductivity of the cell medium. The soil conductivity affects the drive voltage for the cells, whereas the cell medium conductivity determines the portion of the drive voltage that is seen across the cells. Because of differences in the control circuitry for the two cell types, a change in cell medium conductivity will have its greatest impact on matched electric field cells.

4.3 ELF Interference Susceptibility and Lightning Protection for Monitoring Equipment

In 1987 and 1988, IITRI assisted in analyzing the ambient monitoring systems at the upland flora and soil microflora study sites to determine the susceptibility of the systems to ELF interference, and to help design lightning protection for the monitoring equipment. Specific areas of concern that were addressed were:

- the magnitude of ELF voltages accessible to the public on metallic sensor housings and cables (touch voltage)
- the magnitude of ELF voltages accessible to study investigators on wires and terminals inside sensor housings and junction boxes (craftsman safety)
- the possibility of ELF interference to sensor signals
- the design of lightning protection for the remote sensors and the Handar 540 monitoring platform

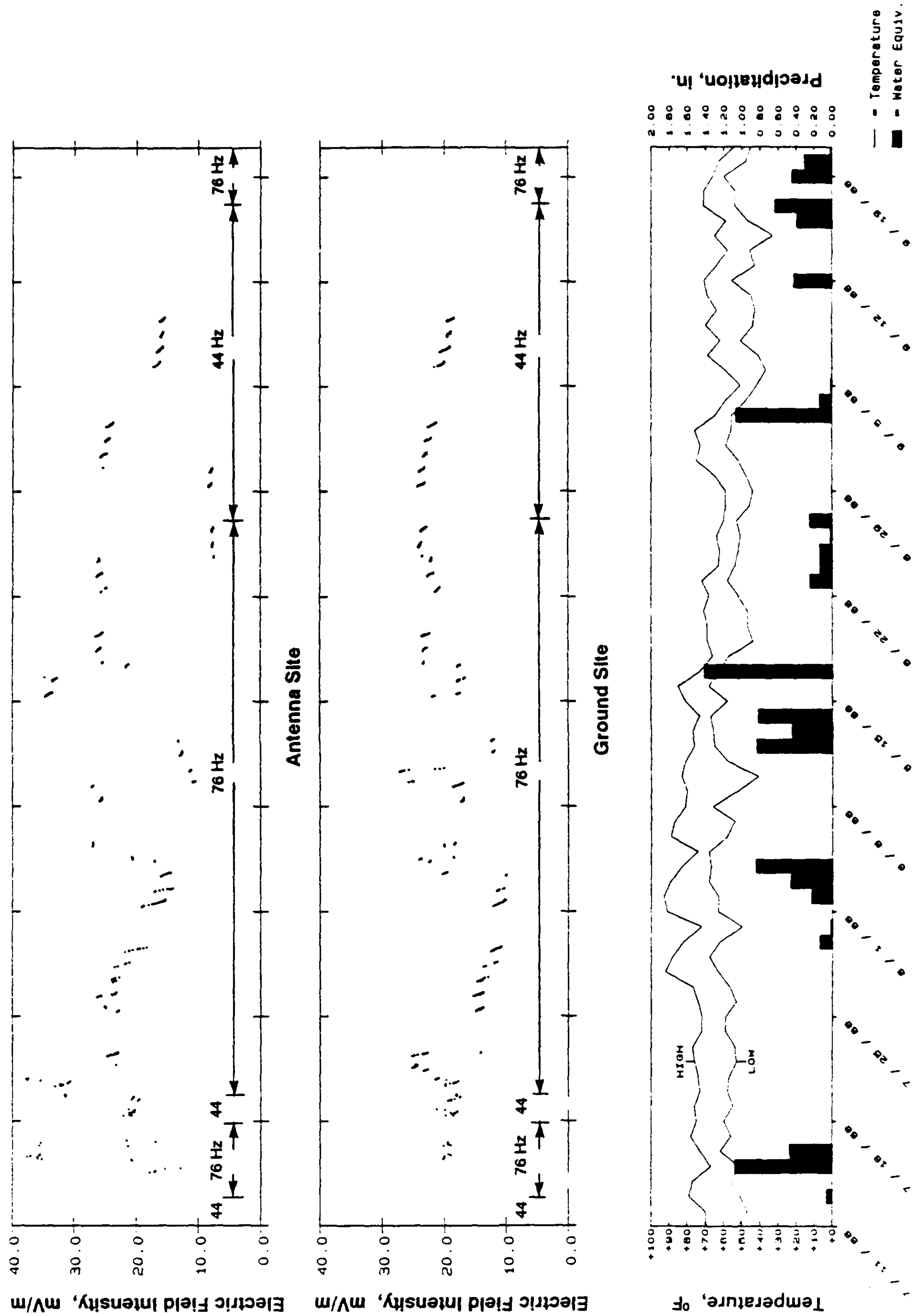


FIGURE 11. HOURLY EM FIELD MEASUREMENTS FOR MATCHED ELECTRIC FIELD CELLS AT SOIL AMOEBA ANTENNA AND GROUND STUDY SITES.

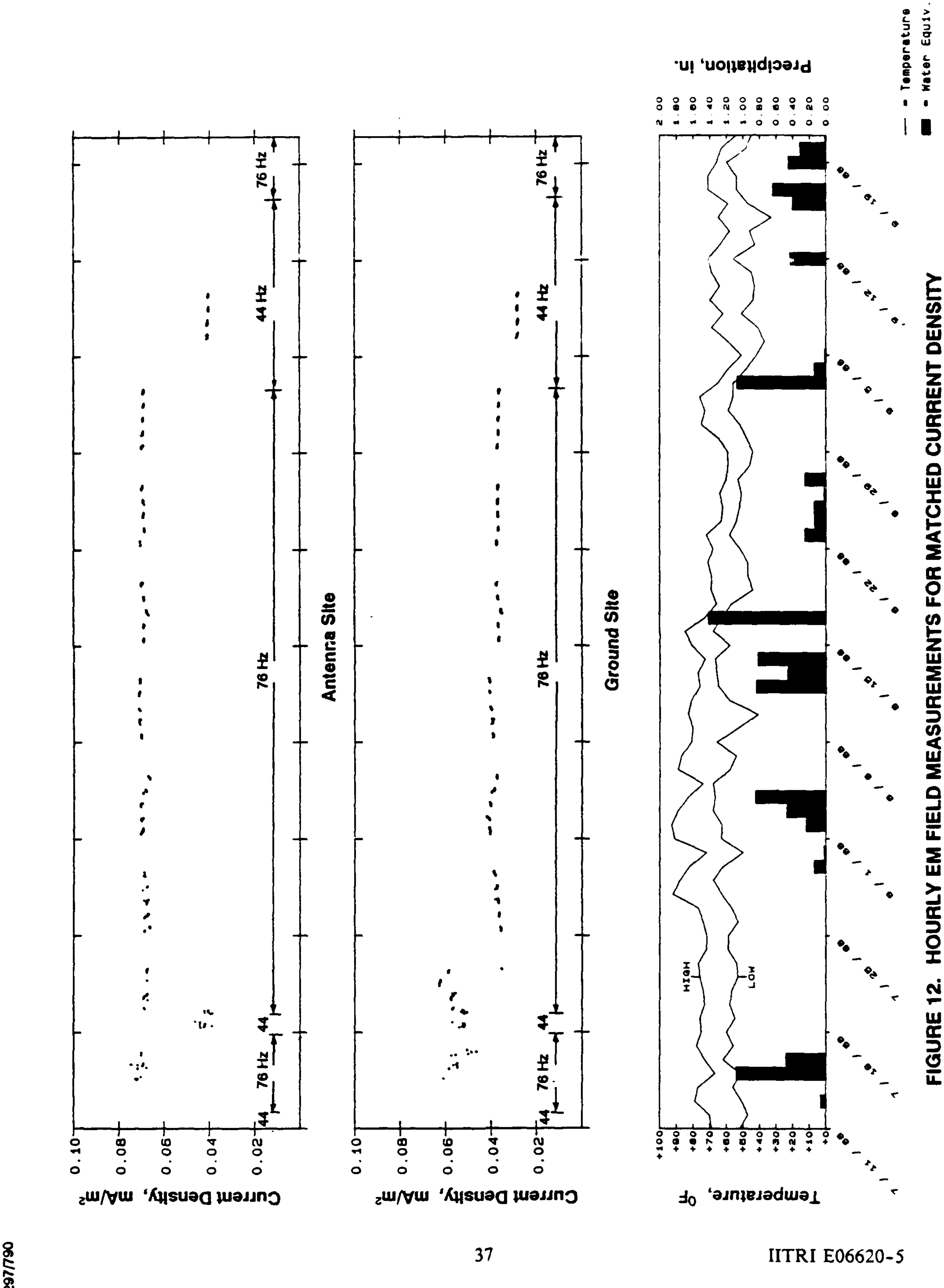


FIGURE 12. HOURLY EM FIELD MEASUREMENTS FOR MATCHED CURRENT DENSITY CELLS AT SOIL AMOEBA ANTENNA AND GROUND STUDY SITES.

Impedance measurements of ground rods used for lightning protection and touch potential reduction showed high ground rod impedances due to the sandy nature of the soil. These high impedances were reduced by treating the ground rods with magnesium sulfate. Four ground rods at the antenna site, and all ground rods at the control site, which is considered to have the highest risk of lightning damage, were treated with magnesium sulfate. Measurements showed that the salt provided significant improvements in impedances at all treated ground rods.

In May 1989, impedance measurements were taken again at all ground rods. The previously treated ground rods were then retreated with magnesium sulfate, and impedance measurements were taken again at these ground rods. No significant variations from previous years' measurements were seen in the 1989 impedance measurements at any of the ground rods.

4.4 Spatial EM Field Variability

4.4.1 Upland Flora and Soil Microflora Studies

Researchers observed that residual aspen growth (that is, growth beyond that predicted by modeling) at the antenna study site increased steadily from 1986 through 1988. Similar yearly increases in residual aspen growth were not seen at the control study site. These results suggest that the increasing residual aspen growth at the antenna site may be the result of increasing operating currents at the NRTF-Republic in the corresponding years. Therefore, one would also expect residual growth within a given year to be greatest for those trees closest to the antenna, where the ELF EM fields are expected to be the greatest. A detailed characterization of the spatial variability of EM fields at the treatment study sites is important for evaluating this possibility as well as other possible related effects.

In 1989, five measurement locations were added at the antenna site, and eight locations were added at the ground site, in order to characterize the EM field profiles across the study areas. Assuming that the EM field profile does not vary along a line parallel to the antenna, these profile measurements can be used, with noted exceptions, to estimate the EM fields at any location in the study area. Previously, EM fields were estimated by interpolation between two measurement points nearest to the point of interest.

The EM field profiles for the ground site are shown in Figures 13 and 14. Both the magnetic field and the transverse (air) electric field gradients conform well to theoretical prediction. The slight dip in the magnetic field contour over the buried ground wire is likely the result of partial cancellation between the field generated by the overhead feed wire and that from the buried ground wire. The longitudinal (earth) electric field contour (Figure 13) shows the expected deep null directly over the buried ground wire and the field maxima nearby on either side. The symmetrical and consistent roll-off of the longitudinal electric field contour indicates that the bulk soil

conductivity at this site is fairly uniform over a large area. Thus, the accuracy of estimates of the EM fields at the ground test site will be limited primarily by the accuracy of locating the points of interest with respect to the buried ground wire. This will be especially true for points close to the wire, where the field magnitudes change rapidly over small distances.

At the antenna site, the magnetic field profile (Figure 15) also conforms well to theory. Magnetic field estimates based on the measured profile should be very good for distances of 10 m or greater from the overhead wire. Along the southeastern edge of the pine plantation, some variation from the measured profile may occur because changes in terrain elevation close to the wire will affect the absolute distance to the wire, and therefore the field magnitude. The air electric field (Figure 16) behaves predictably in the pine plantation, and air field estimates there should be as accurate as those for the magnetic field. Within the hardwood stands, however, the vertical component of the air electric field produced by the overhead wire is greatly attenuated. Here the air field is primarily horizontal and is generated by the earth electric field. As a result, the air electric field in the stands is less predictable, and the accuracy of field estimates is markedly reduced.

The profile of the longitudinal (earth) electric field intensity across the antenna site is quite irregular (Figure 15). Indeed, the field's intensity does not decrease with distance from the antenna as anticipated, but generally increases across the site. The most plausible explanation for this unusual profile is that the bulk conductivity of the soil is highly variable over both the pine plantation and pole stand. One would, therefore, have low confidence in any estimates of the earth electric field intensities. Should estimates of the longitudinal electric field intensities be required at this site, it is recommended that they be derived by linear interpolation between the nearest measured points, not from the measured profile.

IITRI plans to make additional longitudinal electric field measurements at the antenna site in 1990 in order to better define the spatial variability of the field. These data will be useful in studying the role of the longitudinal electric field in aspen growth variations at the antenna site. Consideration is also being given to installing data loggers and/or fixed probes in order to monitor seasonal variations of the longitudinal electric field at these study sites.

4.4.2 Aquatic Ecosystems Studies

Historically, several treatment/control site pairs for the aquatic ecosystems studies have fallen short of the EM exposure criteria goals that were introduced in Section 1.3. This was accepted early in the site selection process because of limitations in the length of the Ford River over which matched habitats could be found. Figure 17 shows the geographical relationship between all aquatic ecosystems study sites. In 1989, EM exposure ratios for the aquatic ecosystems studies were recalculated for treatment/control site pairs using EM field intensity measurement data from the newly operational ELF system. These ratios are presented in Table 4.

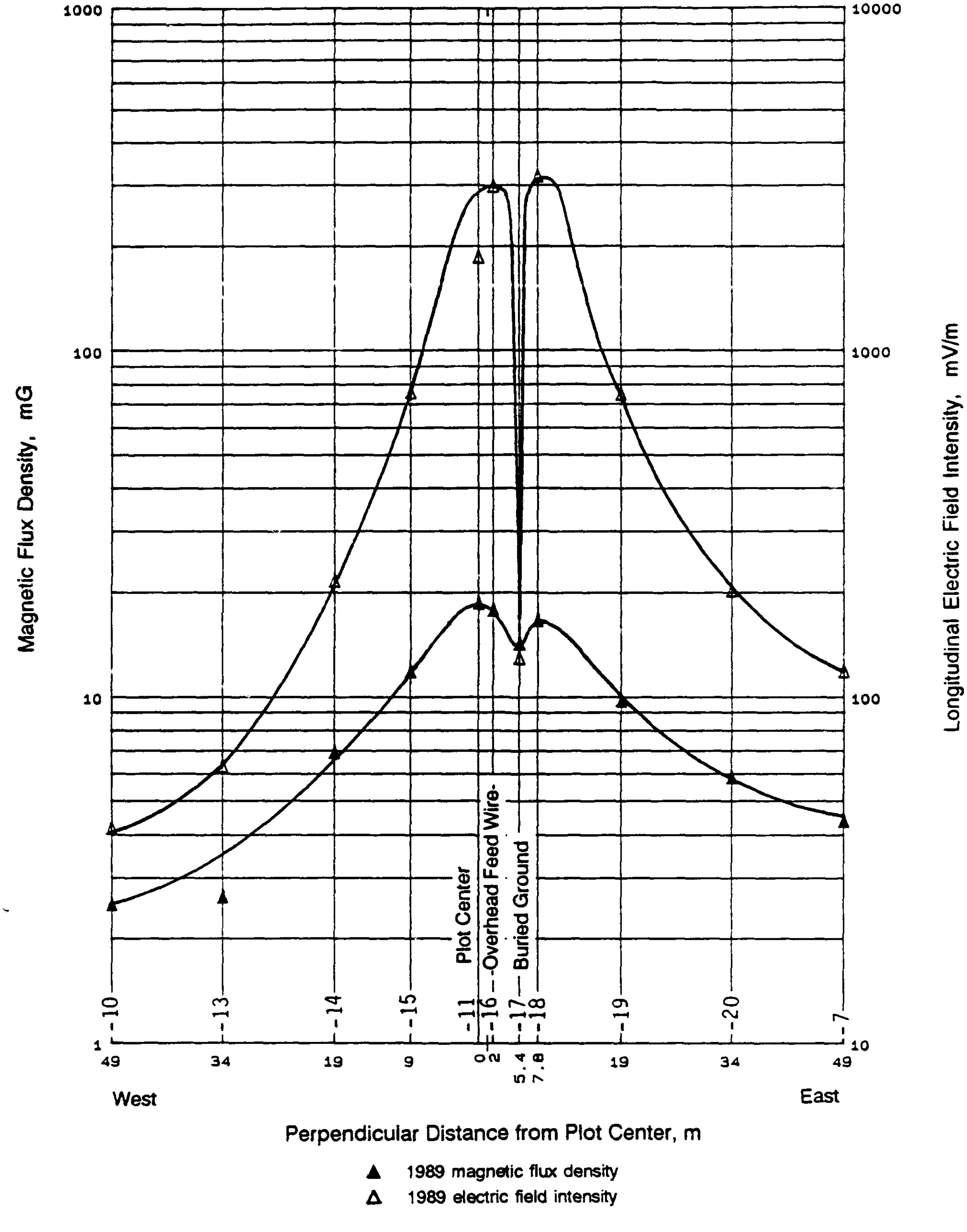


FIGURE 13. 76 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD PROFILES, MARTELL'S LAKE (BURIED): EP; 4T4-7, 10, 11, 13-20.

60297/790

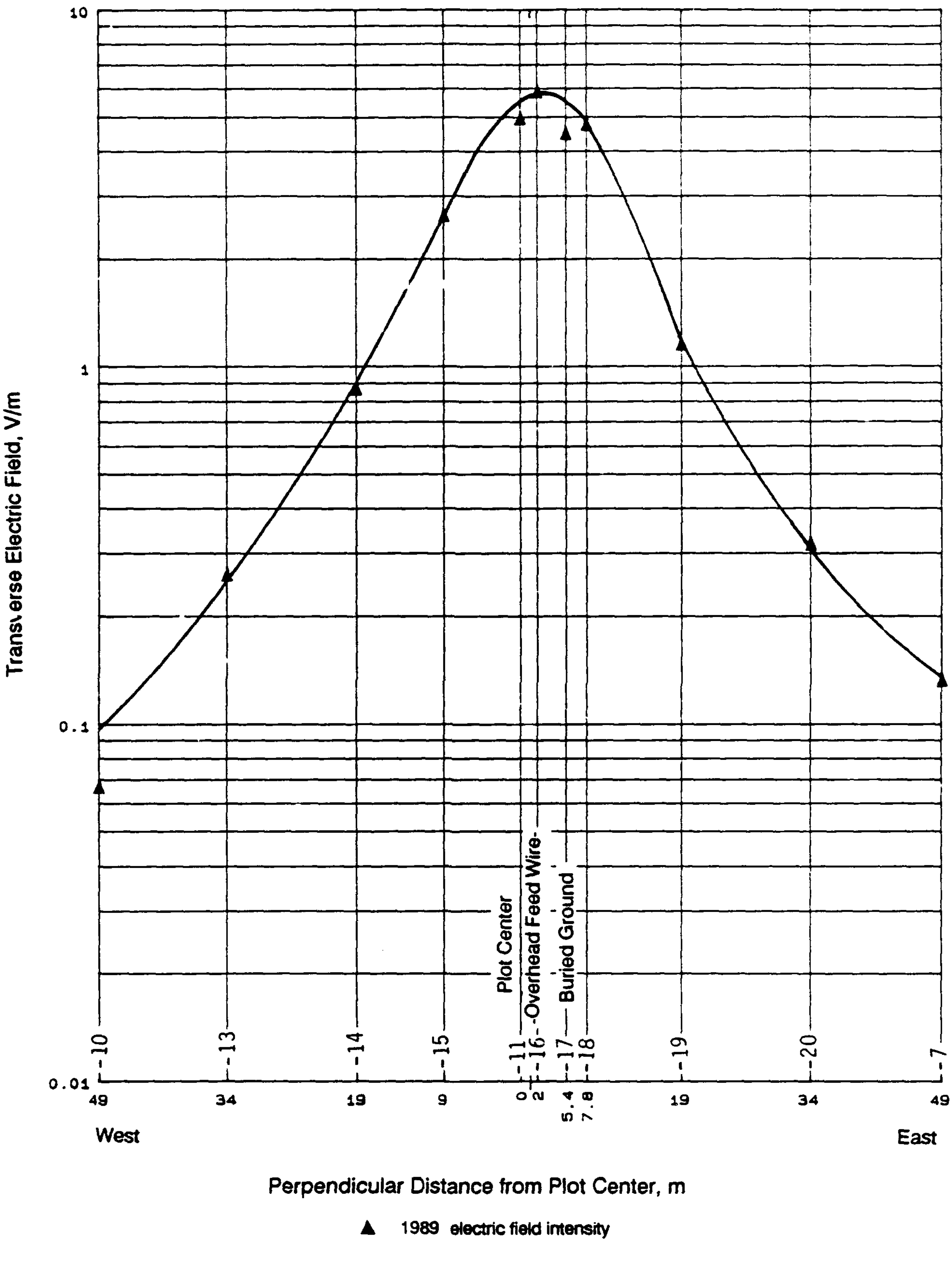


FIGURE 14. 76 Hz TRANSVERSE ELECTRIC FIELD PROFILE, MARTELL'S LAKE (BURIED): EP; 4T4-7, 10, 11, 13-20.

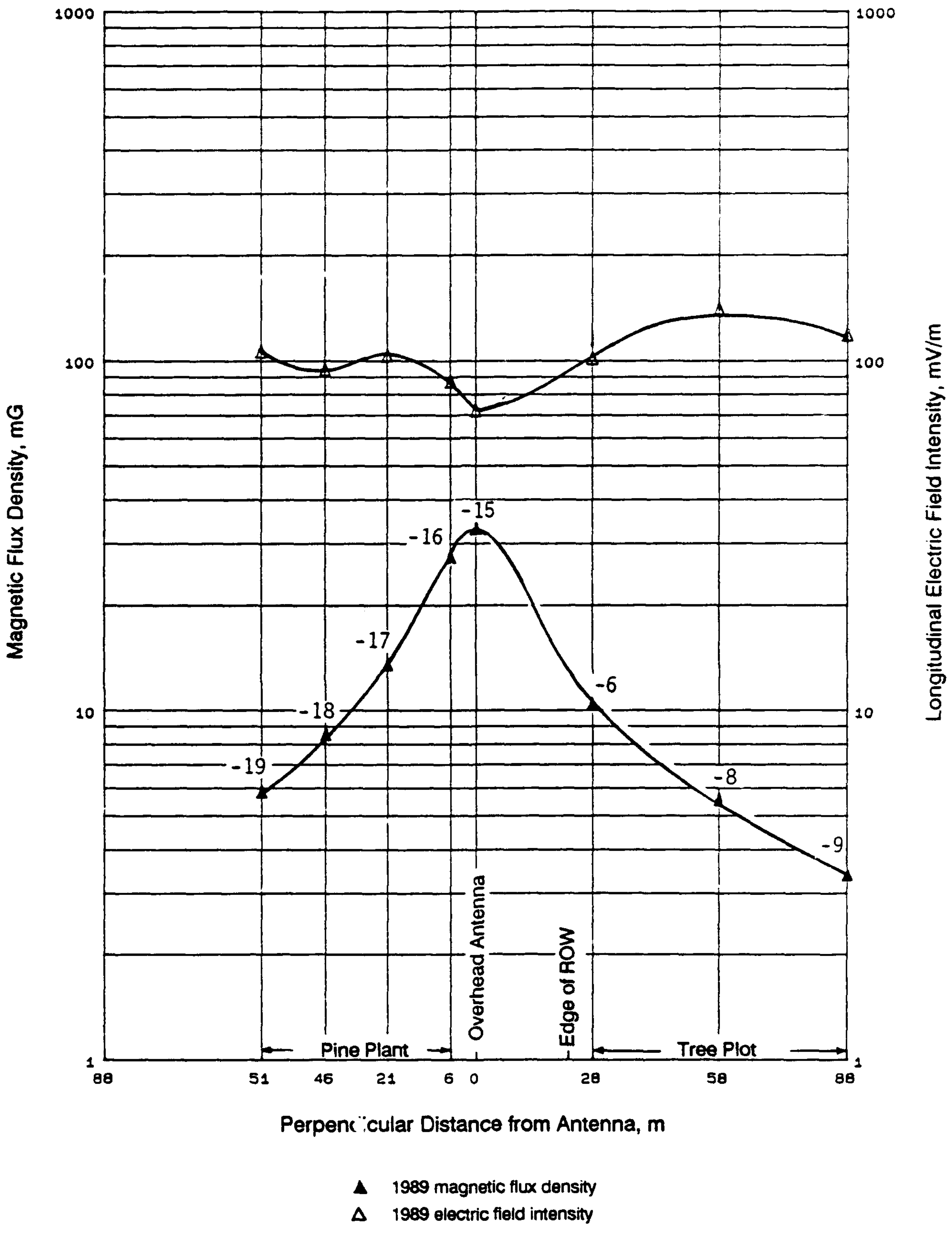


FIGURE 15. 76 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD PROFILES, MARTELL'S LAKE (OVERHEAD): ML; 4T2-8, 9, 15-19.

60297/790

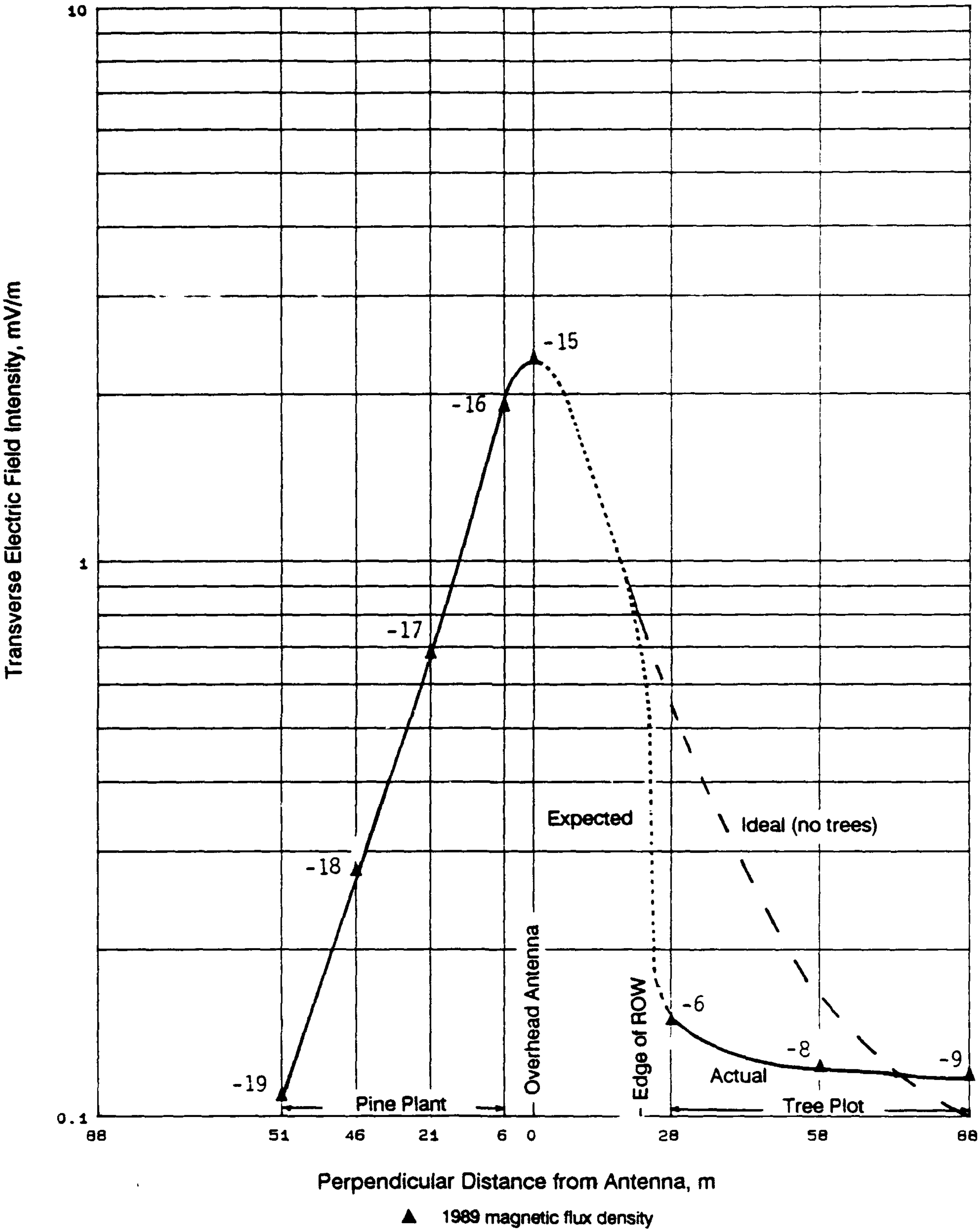


FIGURE 16. 76 Hz TRANSVERSE ELECTRIC FIELD PROFILES, MARTELL'S LAKE (OVERHEAD): ML; 4T2-8, 9, 15-19.

60297/790

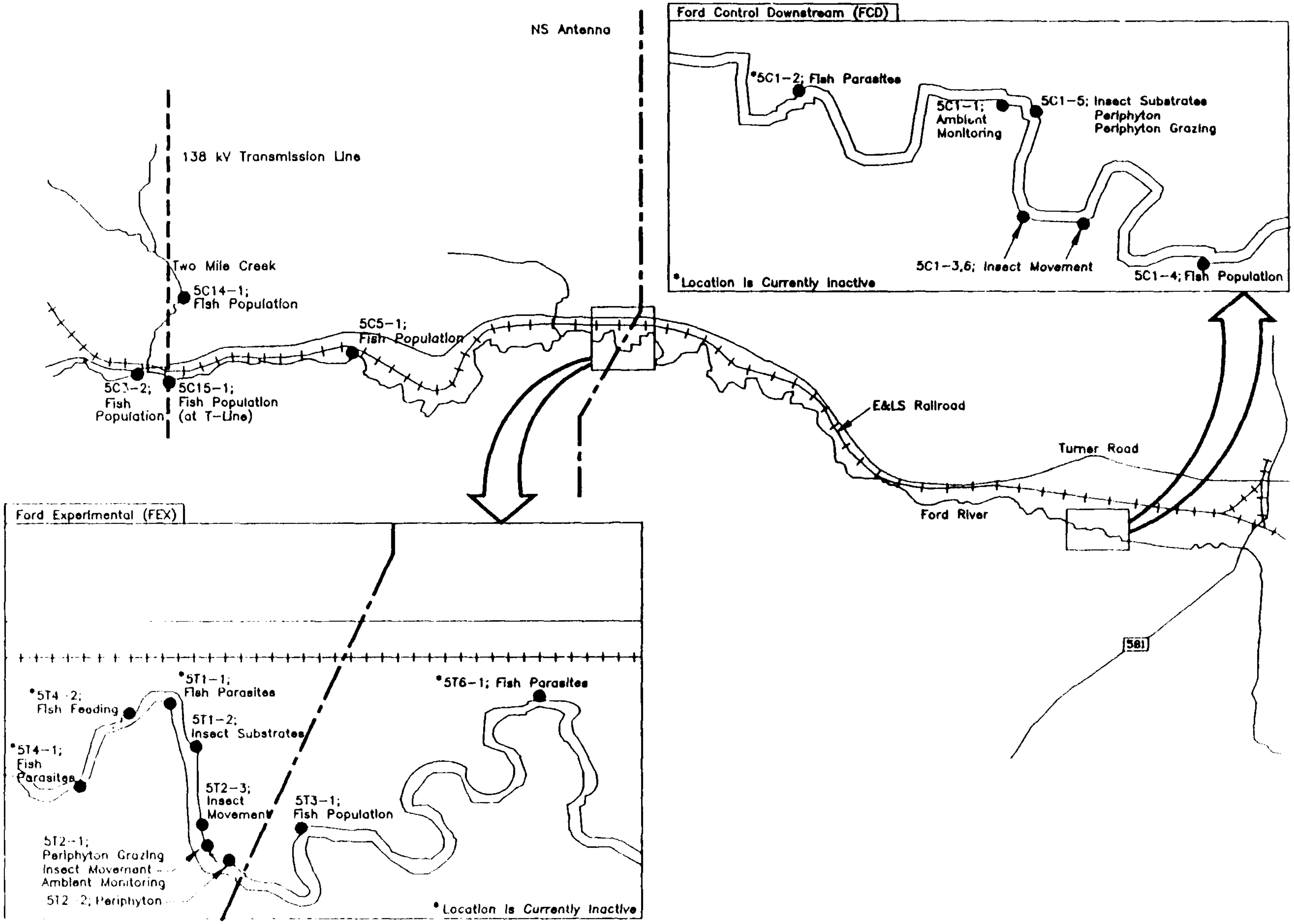


FIGURE 17. AQUATIC ECOSYSTEMS STUDY SITE LOCATIONS.

TABLE 4. 1989 EM FIELD INTENSITY RATIOS
Aquatic Ecosystems Studies

Compared Sites	Activity	Transverse E-Field				Longitudinal E-Field				Magnetic Flux Density			
		R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
5T1-2/5C1-5	Insect Substrates	29	29	29	1.00	2.3	560	82	0.145	61	290	2300	8.0
5T2-2/5C1-5	Periphyton	540	540	540	1.00	5.5	1630	200	0.121	330	1410	12700	9.0
5T2-1/5C1-5	Periphyton Grazing	62	62	62	1.00	3.9	1270	142	0.112	126	1600	4800	3.0
5T2-1/5C1-3	Insect Movement	62	62	62	1.00	6.2	1270	210	0.168	126	1600	4800	3.0
5T2-1/5C1-6	Insect Movement	62	62	62	1.00	6.1	1270	210	0.168	126	1600	4800	3.0
5T2-3/5C1-3	Insect Movement	49	49	49	1.00	5.3	1210	182	0.150	97	1230	3700	3.0
5T2-3/5C1-6	Insect Movement	49	49	49	1.00	5.2	1210	182	0.150	97	1230	3700	3.0
5T3-1/5C1-4	Fish Population	175	175	175	1.00	4.3	390	102	0.26	128	240	2600	10.5
5T3-1/5C3-2	Fish Population	175	175	175	1.00	78	390	410	1.05	134	240	640	2.6
5T3-1/5C5-1	Fish Population	175	175	175	1.00	32	390	1550	4.0	37	240	5100	21
5T3-1/5C14-1	Fish Population	175	175	175	1.00	24	390	35	0.091	85	240	89	0.37

R1 = T(76) / C(76), should be > 10.

R2 = T(76) / T(60), should be > 10.

R3 = T(76) / C(60), should be > 10.

R4 = T(60) / C(60), should be > 0.1 and < 10.

The EM exposure ratios for two of the study elements, insect substrates (5T1-2/5C1-5) and periphyton grazing (5T2-1/5C1-5), continue to be of concern because of their very low values. The 76 Hz exposure ratios for the longitudinal (earth) electric field (R1 ratio in Table 4) at treatment and control sites are noticeably lower than the minimum ratio of 10. However, these ratios may be improved by relocating these studies relatively small distances within the treatment and control stream segments. For example, relocating all activities performed near 5C1-5 downstream 130 meters to the vicinity of 5C1-3 would increase the R1 ratio of the longitudinal electric field by a factor of 1.5. If, in addition, activities at 5T1-2 (insect substrates) and 5T2-1 (periphyton grazing) were moved between the antenna and measurement point 5T2-2 (periphyton), a minimum ratio of 8.5 would be anticipated for the substrates and grazing studies.

In the fish movement studies, the rate of movement of fish is monitored as they swim upstream from site 5C1-4 to 5C3-2. The movement, which can be followed on the map in Figure 17, begins with the release of tagged fish from site 5C1-4 (see inset at upper right of Figure 17). The fish swim upstream from here to a fyke net on the downstream side of the NS antenna at site 5T3-1 (inset at lower left of figure). Times of movement to this point are recorded. The fish are then released again and continue their upstream movement, passing underneath the NS antenna and a 138 kV transmission line, and are finally recaptured at fyke nets at sites 5C3-2 or 5C14-1, where times of movement are again recorded. Both movement times and rates of recapture along the two stream segments are considered in the study of possible effects of EM fields on fish movement patterns.

EM fields were measured at the point where the transmission line crosses the Ford River for the first time in 1989. As anticipated, these fields were the largest of all 60 Hz EM fields measured at aquatic ecosystems study sites. At the time of the measurements, the 60 Hz longitudinal electric field under the transmission line was more than an order of magnitude less than the 76 Hz longitudinal electric fields under the antenna. However, the 60 Hz magnetic flux density was comparable to the 76 Hz magnetic flux density encountered under the ELF antenna. It is important to note that these 60 Hz measurements represent only one sampling, and measurement values will change with electrical loads on the transmission line.

It remains a concern that the 60 Hz EM fields generated by the transmission line could have an effect on fish movement patterns. Furthermore, such an effect could mask possible effects attributable to the ELF system. Researchers plan to address this concern by adding a third stream segment to the river with the addition of a fyke net at a location between the NS antenna and the transmission line. This additional net will isolate stream segments in which 60 Hz and 76 Hz EM fields dominate, allowing for the study and comparison of the effects of these two EM field exposures on fish movement patterns.

4.4.3 Bird Species and Communities Studies

The bird species and communities studies monitor migrating bird population using a census technique involving study transects that are 200 m (600 ft) wide by 4.5 km (2.7 mi) long. Ten transects are located in the NRTF-Clam Lake system area and 10 near the NRTF-Republic. Each transect is subdivided into eight segments. The study involves monitoring the total population of migrating birds in an area, both as a whole and as individual species. The electric and magnetic fields in the air are considered the most important EM factors influencing migrating birds; however, the electric field in the earth may also have an influence.

Early in 1988, the study investigators requested information regarding the gradient of EM field intensities perpendicular to study transects as well as the variability of the EM field intensities along the centerline of the transects. IITRI responded by taking special sets of EM measurements at several Wisconsin transects during the annual EM measurement surveys.

In 1988, profiles of the magnetic and the longitudinal electric fields were characterized with measurements made at regular intervals on a line perpendicular to the NS antenna and study transect 10T8. The measurement data are reported in Appendix G, Table G-6. These measurements define typical gradients of 76 Hz longitudinal electric field intensity and magnetic flux density across the width of the study transect. A graph of the magnetic field data is presented in Figure 18. The magnetic field curve closely matches calculated values, and can be used to predict the magnetic flux density at other locations near an NRTF-Clam Lake antenna element. Similarly, if the magnetic flux density at a location is known, the distance to the antenna can be interpolated from the same curve.

The longitudinal electric field gradient is plotted in Figure 19, and illustrates the changes in intensity of the longitudinal electric field with respect to changes in soil conductivity. This curve, because it is site-specific, cannot be used for estimating electric field intensities or the distances to the antenna from other sites.

Measurements were also made along the centerline of transects 10C7 and 10T8 at the start, finish, historic measurement points, and "X" flags between transect segments. In 1989, the last year for data collection in Wisconsin, special efforts were made to document the EM field variations along the length of the four treatment transects not characterized in 1988: 10T6, 10T7, 10T9, and 10T10. Similar measurements along the four remaining control transects were not performed because the measured EM field variation along control transect 10C7 was shown to be quite small.

EM data for measurements taken along all transects (1988 and 1989) are reported in Appendix G, Table G-7, and are graphed in Figures 20 through 25. The variability in the earth electric fields along treatment transects is due to differences in both the earth's conductivity and the inducing magnetic flux density as a function of location. Differences in the magnetic fields along

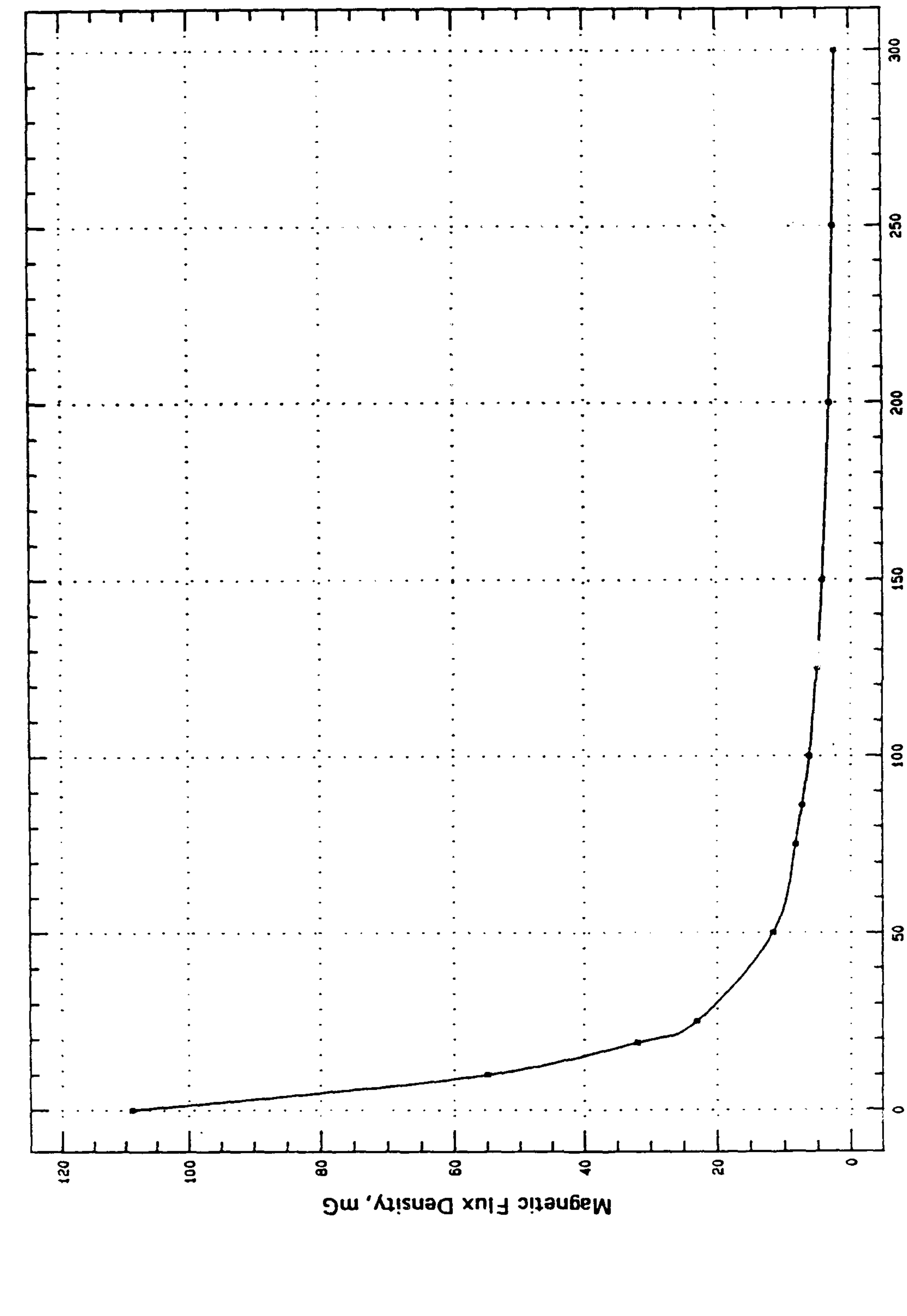


FIGURE 18. MAGNETIC FIELD GRADIENT PERPENDICULAR TO THE NRTF-CLAM LAKE ANTENNA.

60297/790

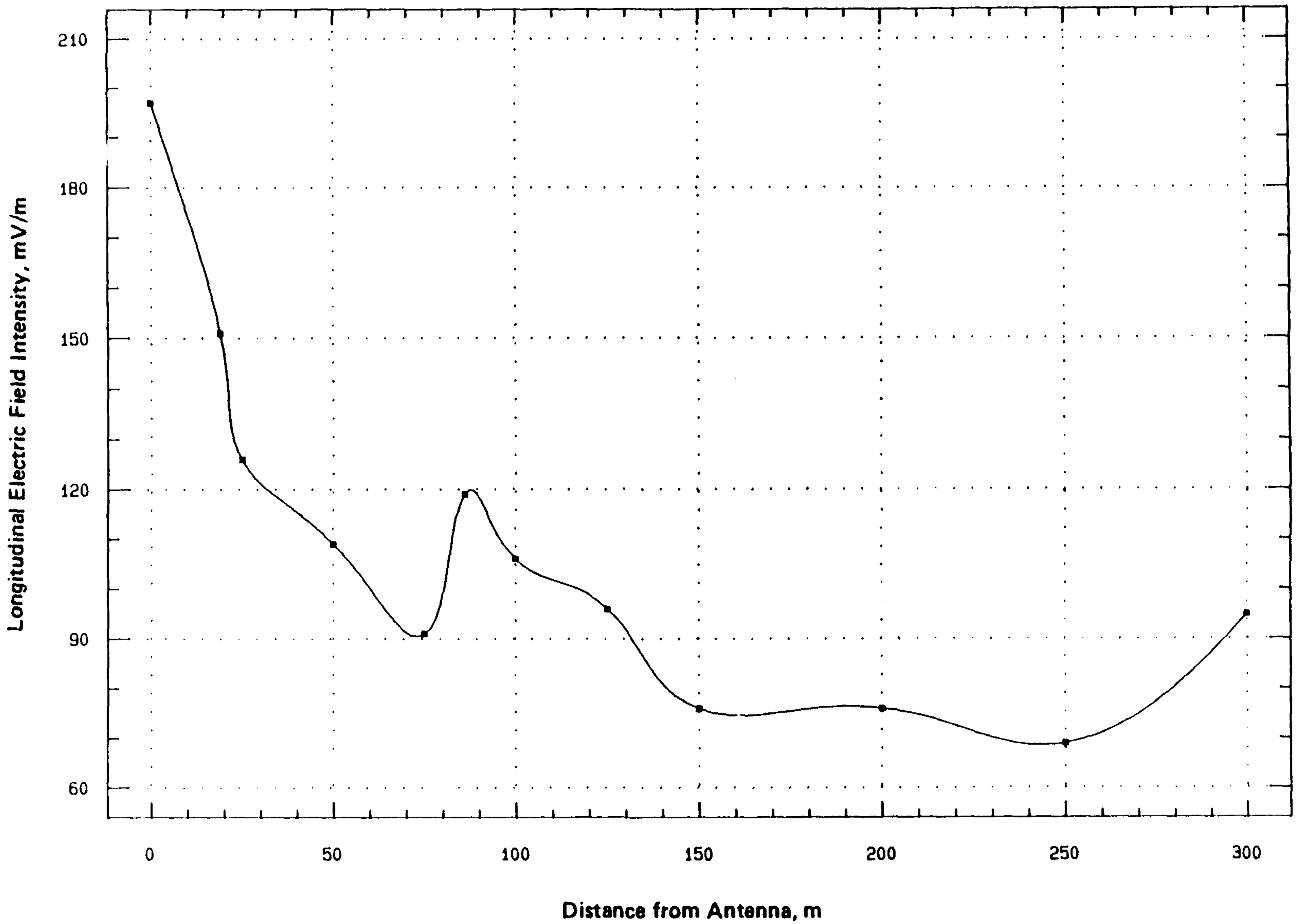


FIGURE 19. LONGITUDINAL ELECTRIC FIELD GRADIENT PERPENDICULAR TO THE NRTF-CLAM LAKE ANTENNA.

60297/790

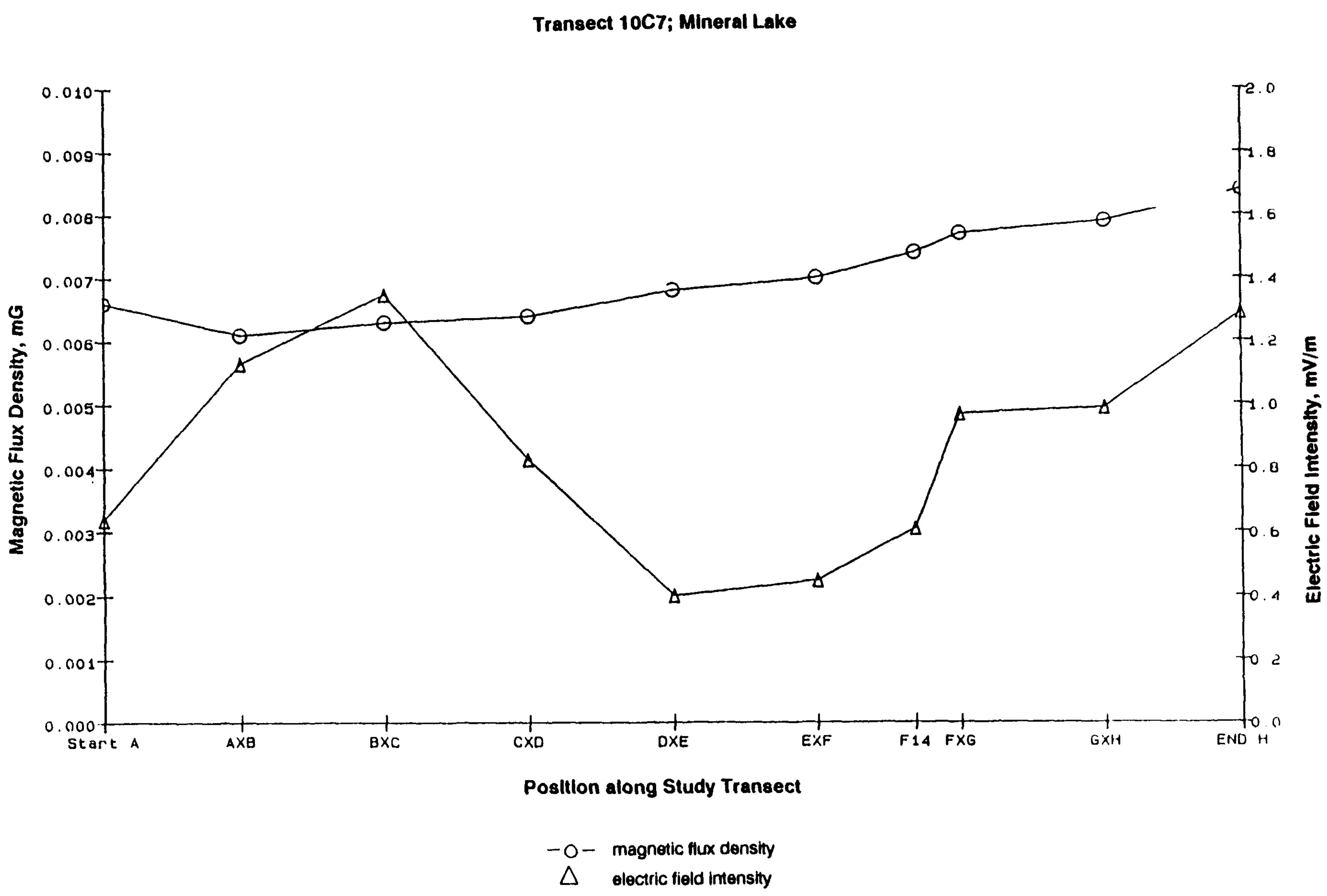


FIGURE 20. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10C7.

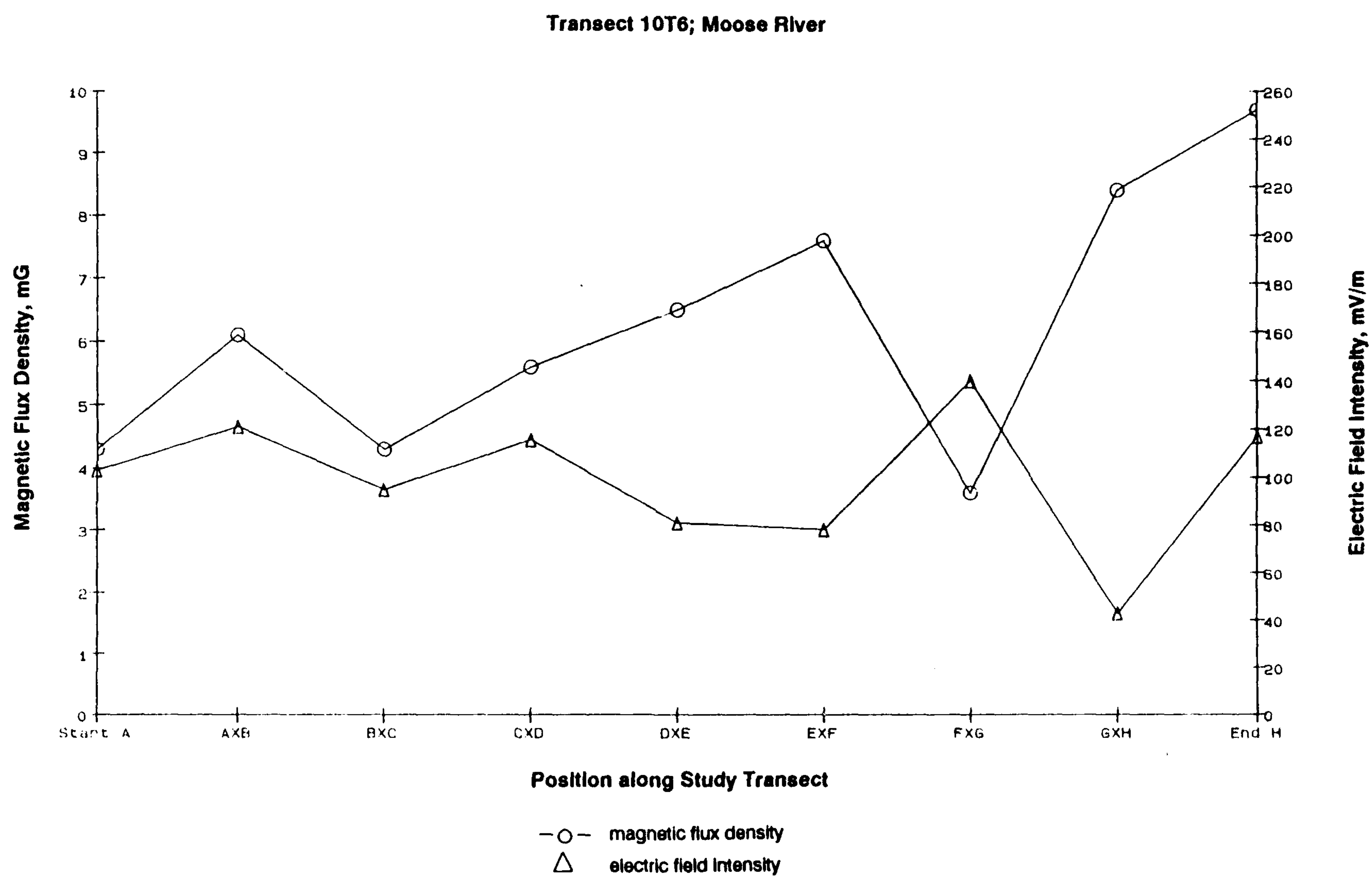


FIGURE 21. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10T6.

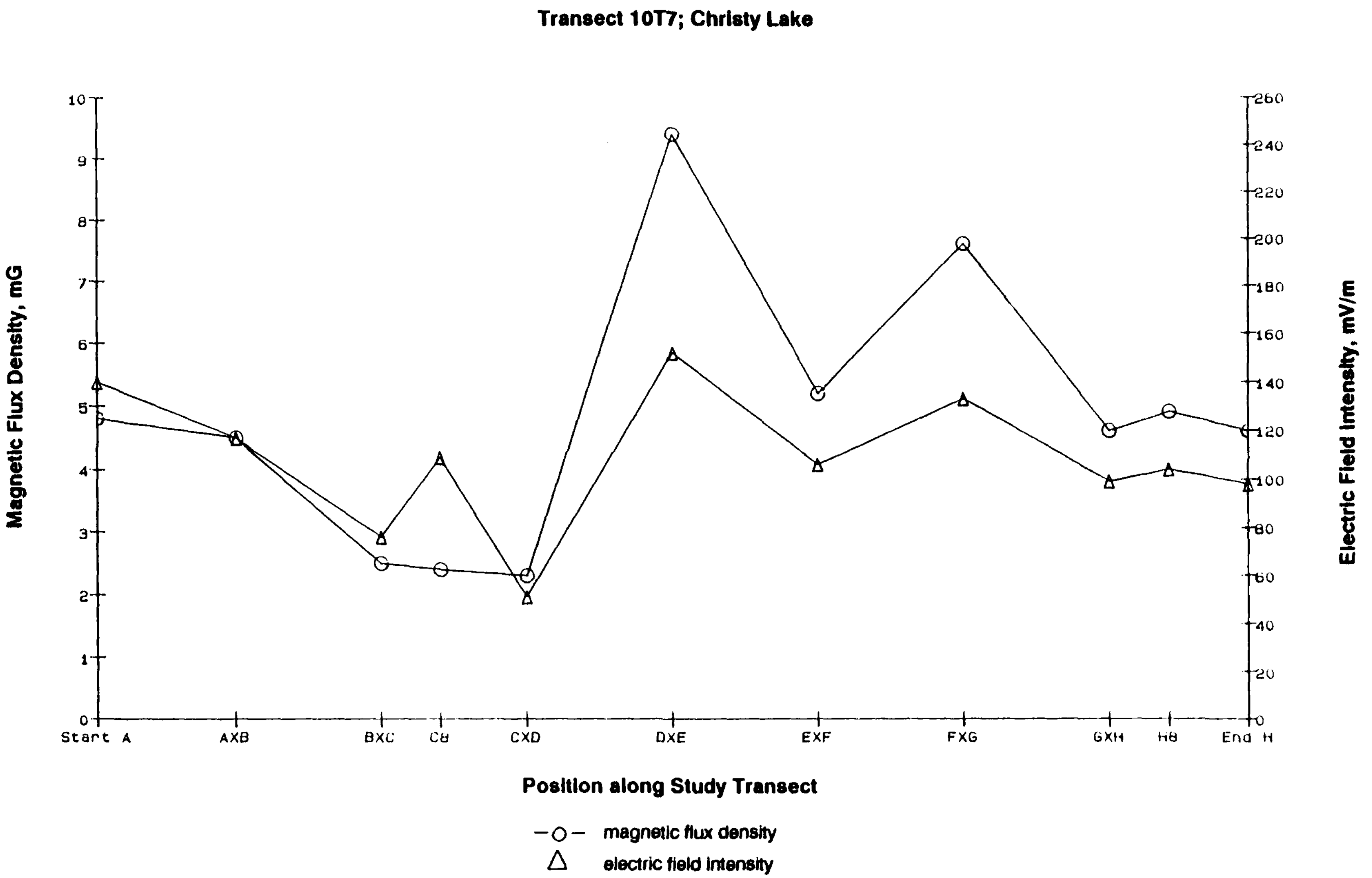


FIGURE 22. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10T7.

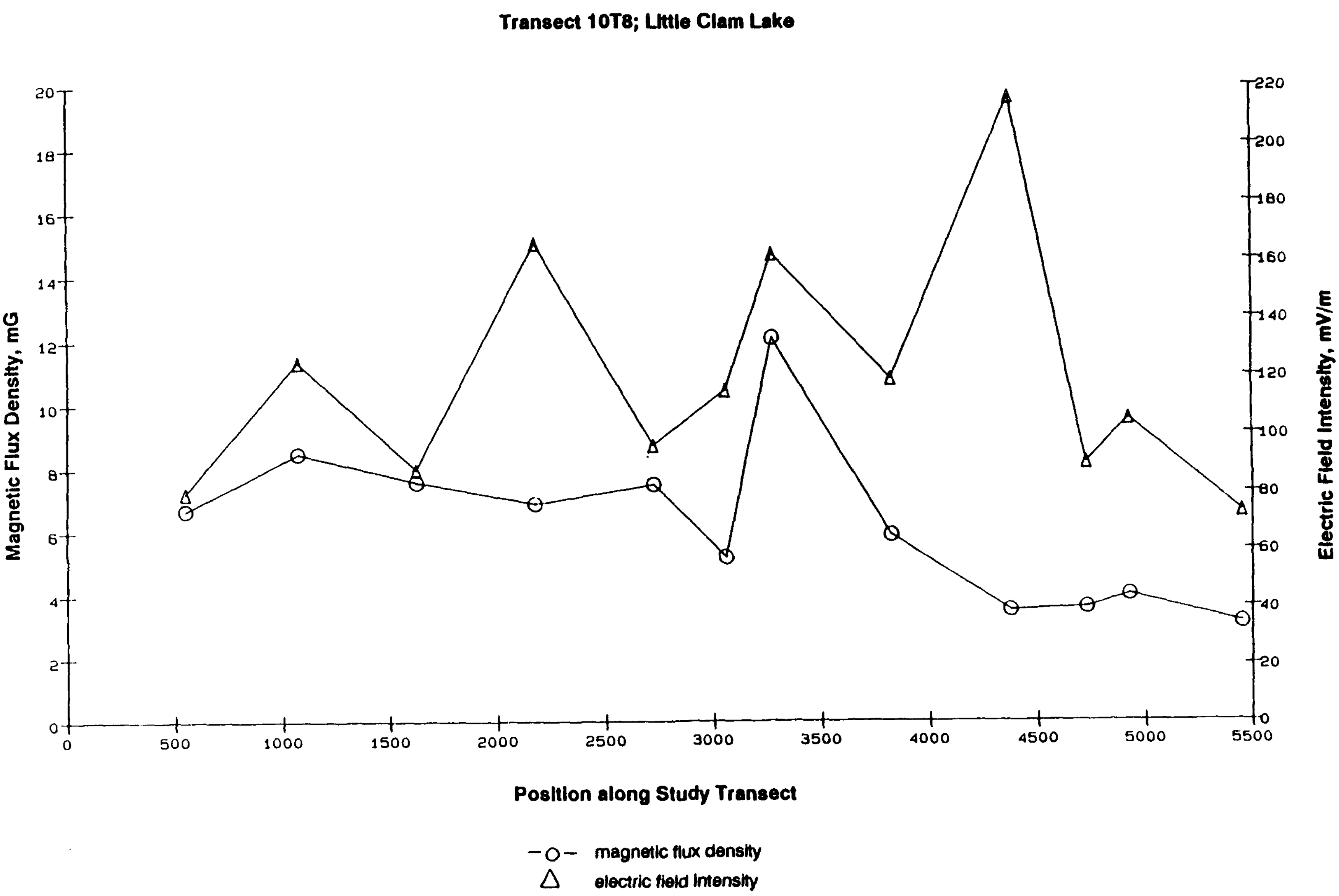


FIGURE 23. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10T8.

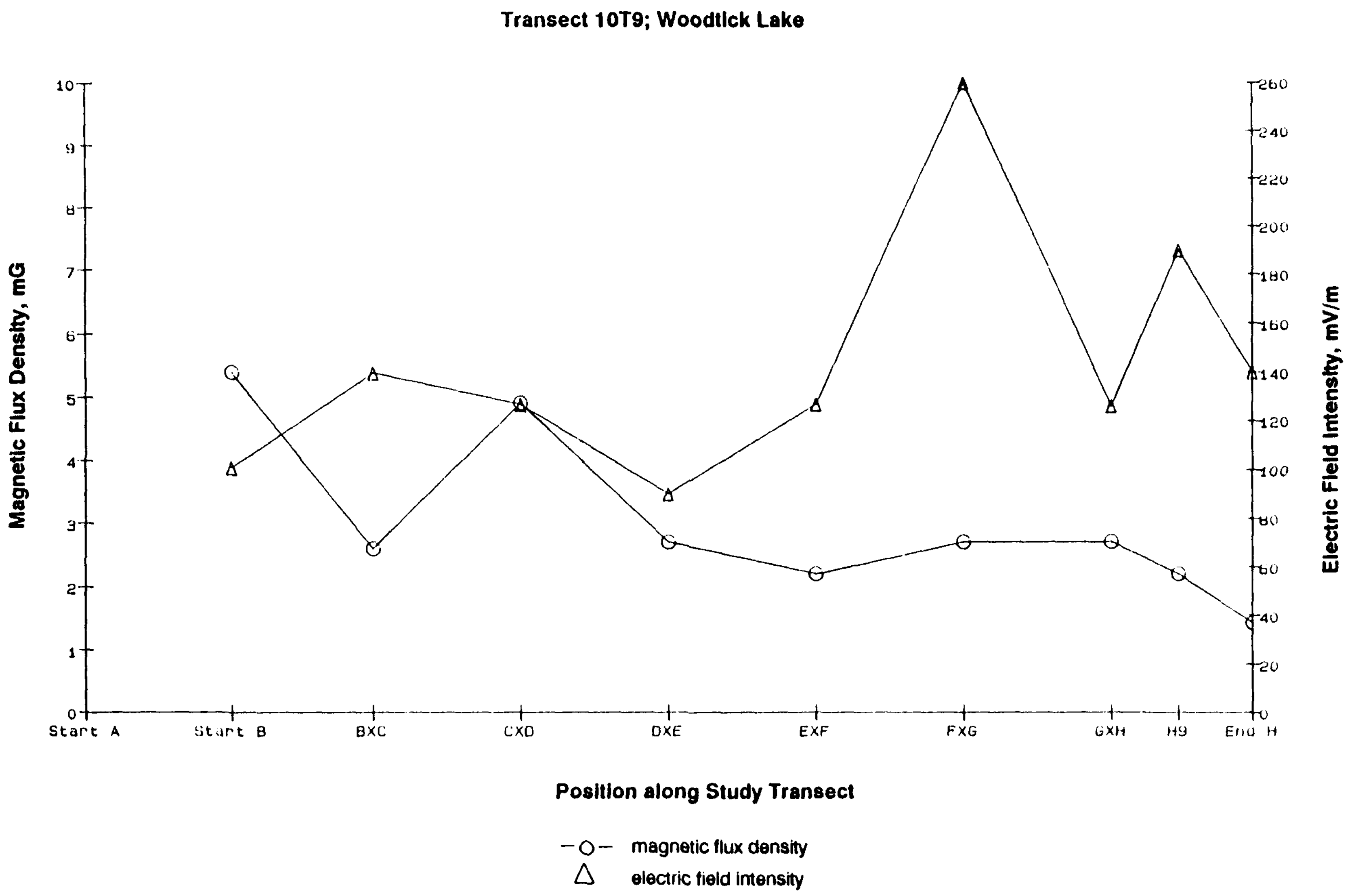


FIGURE 24. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10T9.

Transect 10T10; Black Lake

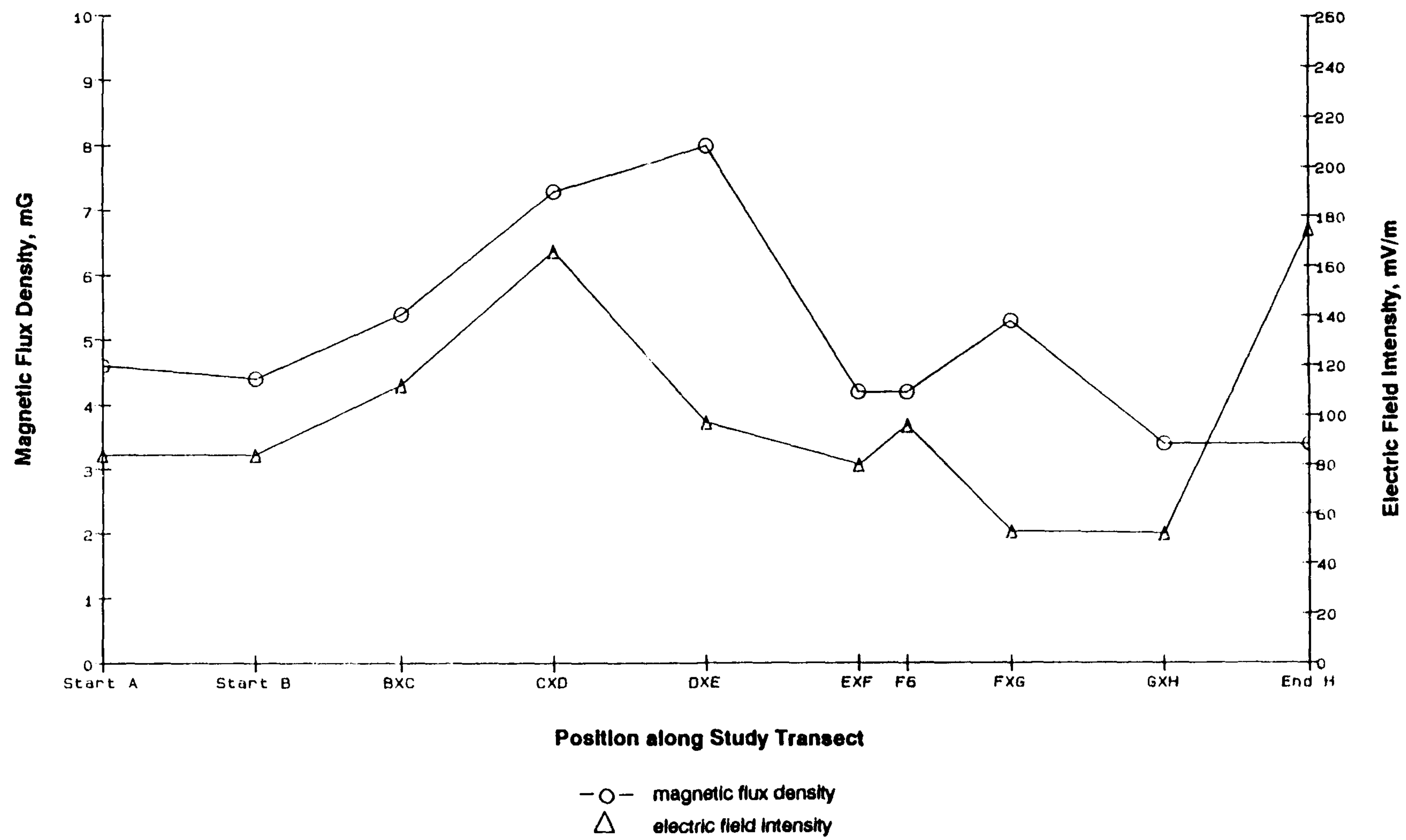


FIGURE 25. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10T10.

test transects result from the varying distances from the transect centerlines to the overhead antenna wire. The earth electric field intensities and magnetic flux densities along Wisconsin treatment transects ranged from 26% to 42% and from 31% to 45% of the mean field values, respectively. This variability is seen as having no effect on intersite relationships, because the treatment/control EM exposure ratios continue to be between 10 and 1000.

4.5 Temporal EM Field Variability

Annual EM field measurements generally have been made in late summer and early fall. Since most study biota remain on the study sites throughout the year, the subject of EM field variations over the course of a year is important. The primary sources of EM field temporal variability are expected to be related to either the operating parameters of the ELF transmitters or to climatic variables such as temperature, rainfall, and soil moisture levels.

It is anticipated that the magnetic fields at study sites will show little or no seasonal variation, because they are not affected by the conductivity of surrounding vegetation and soil. The magnetic field, B, at the earth's surface near an ELF antenna element can be approximated as:

$$B = \frac{\mu_o I}{2\pi \sqrt{x^2 + h^2}} \qquad (7)$$

where B = magnetic flux density

I = antenna current

μ_o = magnetic permeability in free space

h = height of antenna wire

x = horizontal distance to antenna wire

Thus, the magnetic fields are directly proportional to antenna current, and have no frequency dependence.

The transverse, or air, electric field in an ROW or a clearing near the antenna is essentially dependent on the antenna voltage, distance to the overhead wire, and wire height. In these unshielded locations, it is not expected to show significant climatic-induced variation throughout the year. The transverse electric field intensity at the earth's surface can be approximated as:

$$E = \left(\frac{2V}{h\ln\left(\frac{2h}{a}\right)}\right)\left(\frac{1}{1+\left(\frac{x}{h}\right)^2}\right) \tag{8}$$

where E = transverse electric field intensity
V = voltage on antenna wire
h = height of antenna wire
a = radius of antenna wire
x = horizontal distance to antenna wire

It should be noted that the antenna voltage is a direct function of antenna current, and that there is no frequency-dependent term.

At other locations where the transverse electric field is shielded by vegetation and trees or generated as a by-product of the longitudinal electric field, more seasonal variation is expected as plants enter dormancy and leaves fall, or as the longitudinal electric field varies. Such variations in the transverse (air) electric field would be impractical to document to any useful degree.

Longitudinal, or earth, electric fields are induced by the magnetic field as well as being generated by current from antenna ground terminals. In both cases, the field intensities are dependent on soil conductivity, which in turn varies with changes in soil moisture and temperature. The relationship of earth electric fields to soil conductivity for the two field sources is discussed below.

The longitudinal electric field along an ELF horizontal ground terminal is generated primarily by current flowing off the ground wire to the earth, and can be approximated as:

$$E = \left(\frac{I}{\pi l \sigma_s}\right)\left(\frac{x}{x^2 + d^2}\right) \tag{9}$$

where E = longitudinal electric field
I = ground wire current
l = ground length
d = depth of buried ground wire
x = horizontal distance from ground wire
σ_s = surface earth conductivity

The magnetically induced longitudinal electric field near an antenna ROW can be approximated as:

$$E \simeq jfI\mu_o \ln\left(\frac{1.85}{x\sqrt{2\pi f\mu_o\sigma_B}}\right) - \frac{\pi fI\mu_o}{4} \quad (10)$$

where E = longitudinal electric field

$j = \sqrt{-1}$

f = frequency

I = antenna current

μ_o = magnetic permeability in free space

x = horizontal distance from antenna

σ_B = bulk earth conductivity

Equations 9 and 10 illustrate differences in the variation of the longitudinal electric field near ground terminals and antenna ROWs, respectively, as a function of current, frequency, and soil conductivity. Note that the ground wire electric field is dependent on the ground wire current, while the magnetically induced electric field is dependent on the antenna current and on frequency. In both equations, earth conductivity is the only variable that is expected to show a seasonal variation. The two conductivity terms (bulk and surface) are not equivalent, and have different functional relationships within the corresponding electric field equations. The longitudinal electric field near ground terminals is dependent primarily on surface earth conductivity, while bulk earth conductivity determines the electric field near antenna ROWs.

The bulk earth conductivity is a weighted average of the surface and deep earth conductivities. Because the deep earth conductivity remains stable throughout the year, the bulk earth conductivity shows less seasonal variation than does the surface earth conductivity. In addition to these differences in conductivity, the longitudinal electric field near ground terminals is inversely proportional to conductivity, while the longitudinal electric field along antenna ROWs is proportional to the natural logarithm of the inverse of the square root of conductivity. Thus, the longitudinal electric field is almost twice as sensitive to changes in conductivity near ground terminals as it is to changes in conductivity along antenna ROWs. This fact, in conjunction with the expected higher variation in surface conductivity, indicates that the greatest seasonal variations in longitudinal electric fields will occur along ground terminal ROWs. Additional earth electric field variability can result if either conductivity is itself frequency dependent.

4.5.1 Measured Seasonal Variations

Data loggers at the soil amoeba study sites are kept on site all year in order to monitor variations in the longitudinal electric field. Electric field data from two study sites, one adjacent to an antenna ROW and the other adjacent to a ground ROW, are presented in Figures 26 and 27, respectively. These figures plot daily averages of hourly longitudinal electric field measurements taken while the NS antenna operated with a 75 ampere current and either a 44 Hz or 76 Hz frequency. The data covers the period from July 1988 through December 1988.

The NRTF-Republic operated at several different frequencies in either the 44 Hz or 76 Hz transmitting ranges during the periods plotted in Figures 26 and 27. The impact of a 44 Hz operating frequency on the electric field intensity is the greatest at the antenna site, where the electric field, generated by magnetic induction, is proportional to the operating frequency of the NRTF-Republic (see Equation 10). The electric field intensity at the antenna site during 44 Hz operation is therefore roughly 60% of the intensity during 76 Hz operation. The air electric field intensity and magnetic flux density are not affected by the change in frequency.

On 22 July 1988, there was a redistribution of currents at ground 4, by which the current being fed into the section of horizontal ground wire adjacent to the study site was decreased. This led to a decrease in the electric field at the ground study site proportional to the decrease in current, which can be seen in Figure 27.

These data on electric field versus time suggest that seasonal field variations near an antenna ROW are roughly on the order of ±5%. As expected, seasonal electric field variations near ground terminal ROWs are somewhat greater, approaching ±20%. Figure 27 shows variations in the electric field that may be correlated with the weather. For example, as the soil moisture increases with rainfall, the upper soil conductivity will presumably increase; hence, the electric field will decrease. This can be seen in early August 1988 as rainfall ended a period of drought.

Only two study sites in Michigan are actually situated in or near ground terminal ROWs. All others are along antenna ROWs and are generally in loamy soil. Seasonal variations in the longitudinal electric field can be expected to have the greatest impact on studies investigating subterranean biota, i.e., the soil arthropods and earthworms studies, the upland flora and soil microflora studies, and the soil amoeba studies. The aquatic ecosystems studies should have the lowest seasonal variation in longitudinal electric field because of the relatively constant bulk conductivity of the Ford River, where these studies are performed.

60297/790

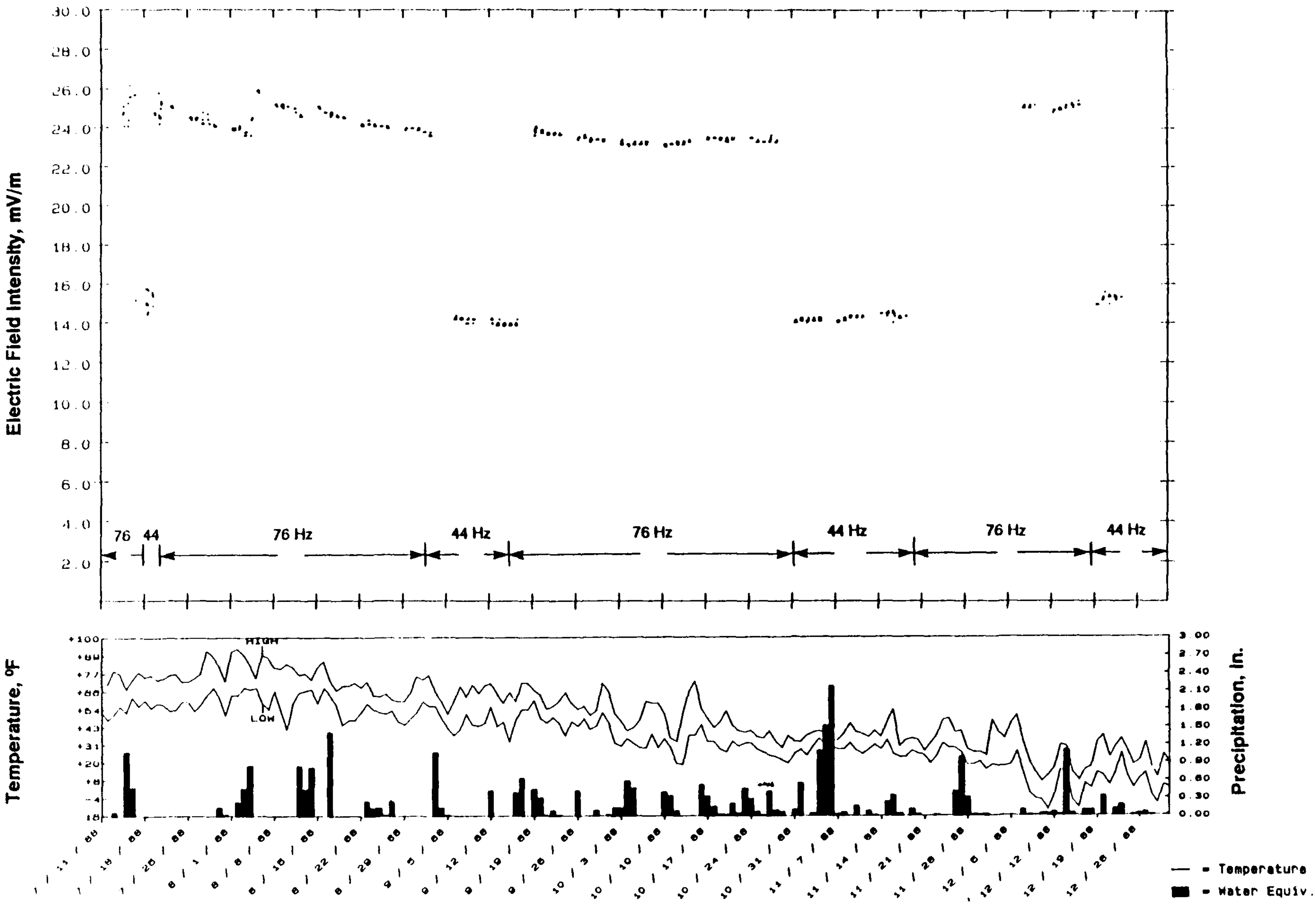


FIGURE 26. HOURLY LONGITUDINAL ELECTRIC FIELD MEASUREMENTS NEAR AN ELF ANTENNA ELEMENT.

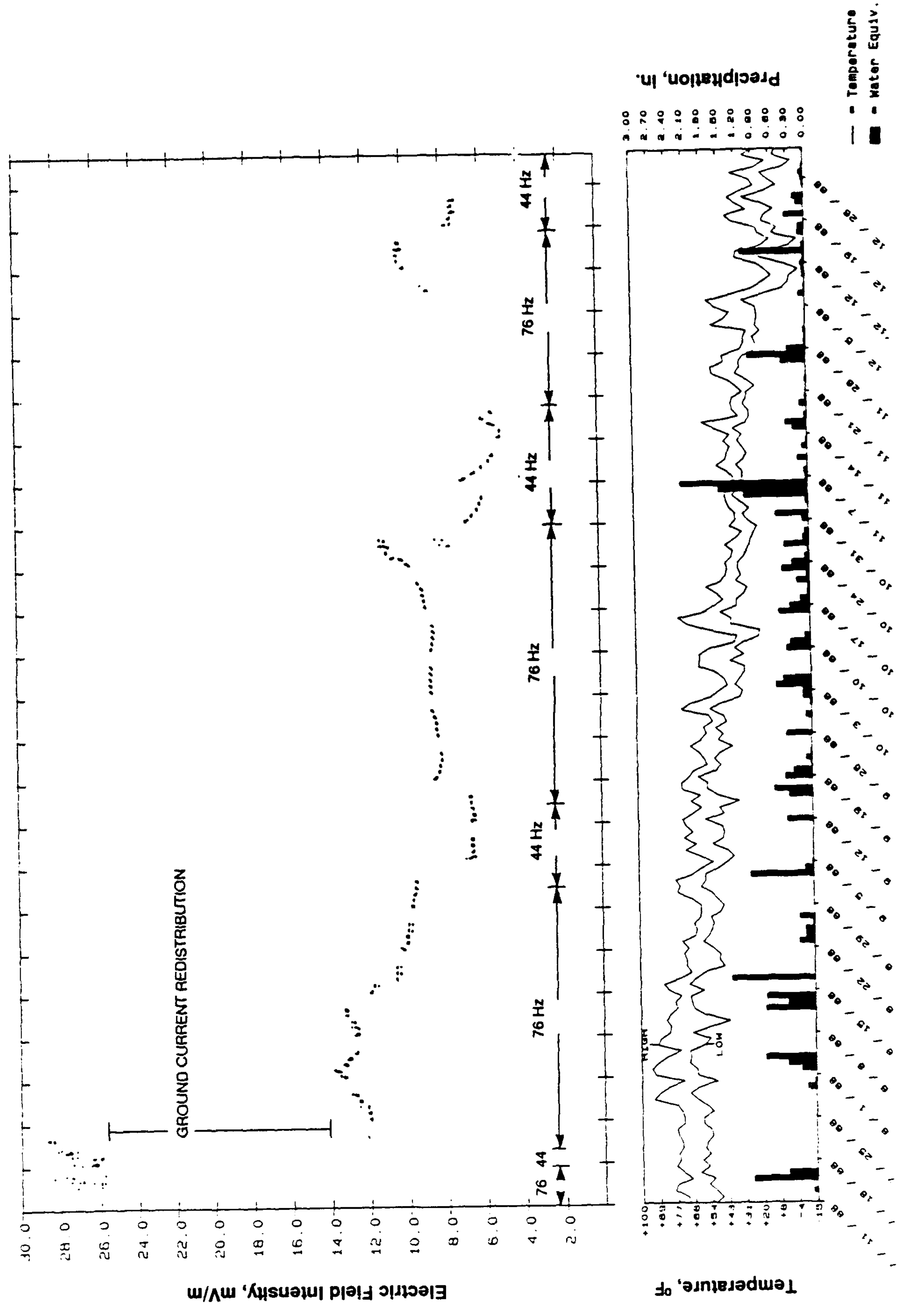


FIGURE 27. HOURLY LONGITUDINAL ELECTRIC FIELD MEASUREMENTS NEAR AN ELF GROUND TERMINAL.

60297/790

4.5.2 Transmitter Operations--Analysis and Data Base

4.5.2.1 Operating Log Data Base. In order to calculate the EM exposure regimes, study investigators must have both field intensity measurements at the study sites and data on the operating times of the antennas. Field intensity measurements were discussed in Section 3, and data tables are presented in Appendixes A through G. Data on antenna operating conditions are provided to IITRI by the Navy's Submarine Communications Project Office. These data include changes in the operating frequency, modulation, power, and phasing for each antenna element. This information is entered into a computer-based spreadsheet that allows the generation of operating condition summaries in both graphic and tabular form. Graphic summaries for both the NRTF-Clam Lake and the NRTF-Republic are presented in this section; more detailed tabular summaries appear in Appendix K. IITRI provides the data bases to study investigators on request.

4.5.2.2 Summary of NRTF-Clam Lake Operations, 1984-1989. The NRTF-Clam Lake has gone through three stages of development from an operational standpoint. The first stage began in the late 1960s, when the NRTF-Clam Lake was constructed as a test system for a Navy ELF communications system. The test procedures required various modulations, frequencies, currents, and separate as well as simultaneous powering (at various antenna current phase angles) of the NS and EW antennas. This stage was marked by sporadic periods of operation.

The second stage began in early 1985 with the installation of the new transmitter equipment. This stage was marked by short powerings interspersed with long periods when the NRTF-Clam Lake was not powered.

After this initial test period was completed, the third stage began: the NRTF-Clam Lake began operational testing, operating nearly 24 hours a day at a predetermined current level, frequency, modulation, and antenna phase angle.

The changes from one stage to the next are represented clearly in the NRTF-Clam Lake monthly operating summary bar graph of Figure 28. This figure shows the hours of operation on a month-by-month basis for the years 1984-1989. Operation of both antennas simultaneously was predominant in 1984, with only sporadic operation of the antennas individually. There was little operation of the NRTF-Clam Lake in the first quarter of 1985, followed by intermittent operation in the second and third quarters, and nearly full-time operation in the fourth quarter. This nearly full-time operation continued through 1988. In 1989, full-time operation was interrupted by special maintenance operations and tests performed in conjunction with the NRTF-Clam Lake.

Figure 29 provides a bar graph of the annual operating summary of the NRTF-Clam Lake by mode of operation for 1984-1989. As indicated, the predominant operating condition for all four years was modulated signal transmission at a center frequency of 76 Hz.

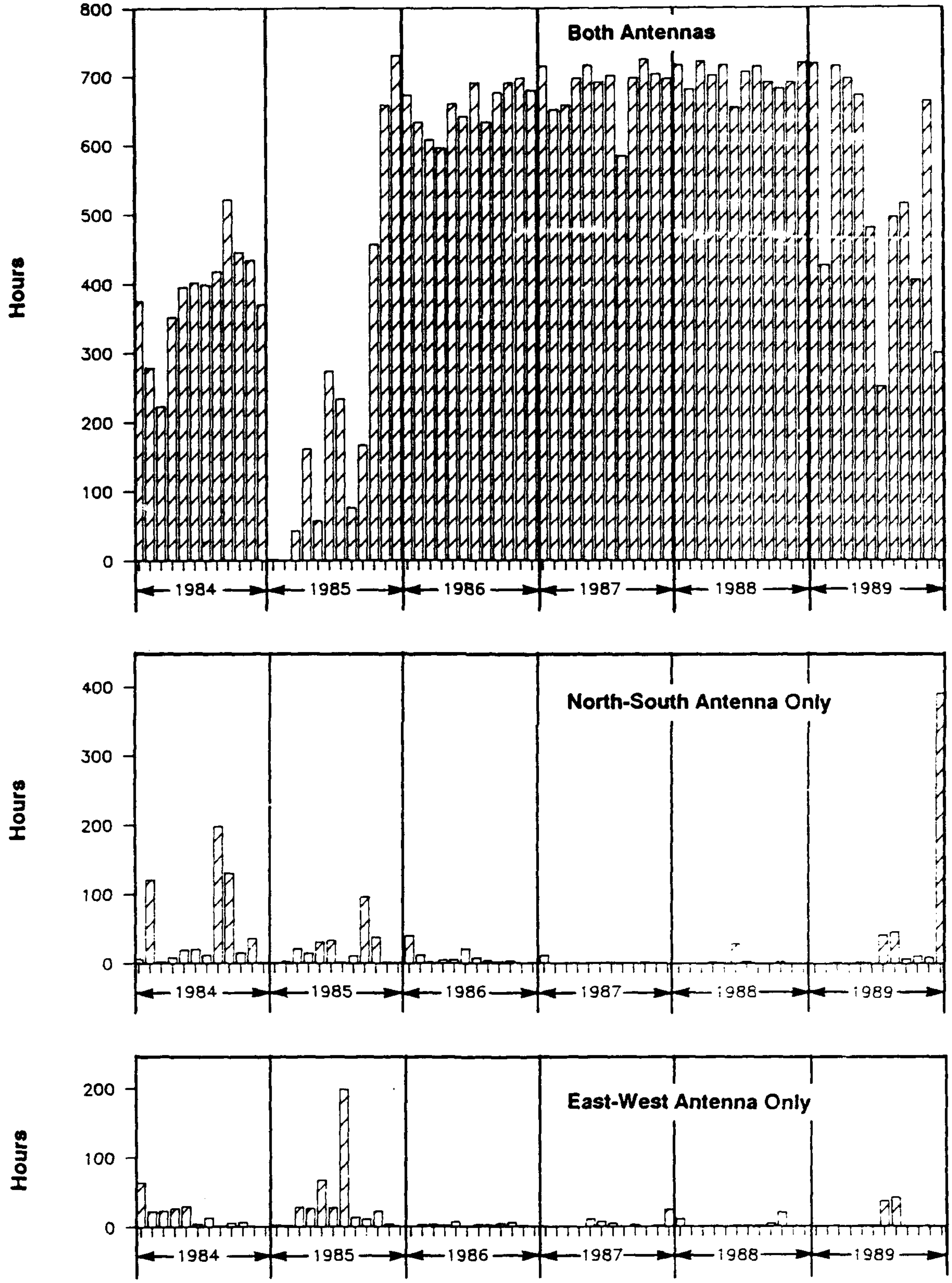


FIGURE 28. NRTF-CLAM LAKE MONTHLY OPERATING SUMMARY, 1984-1989.

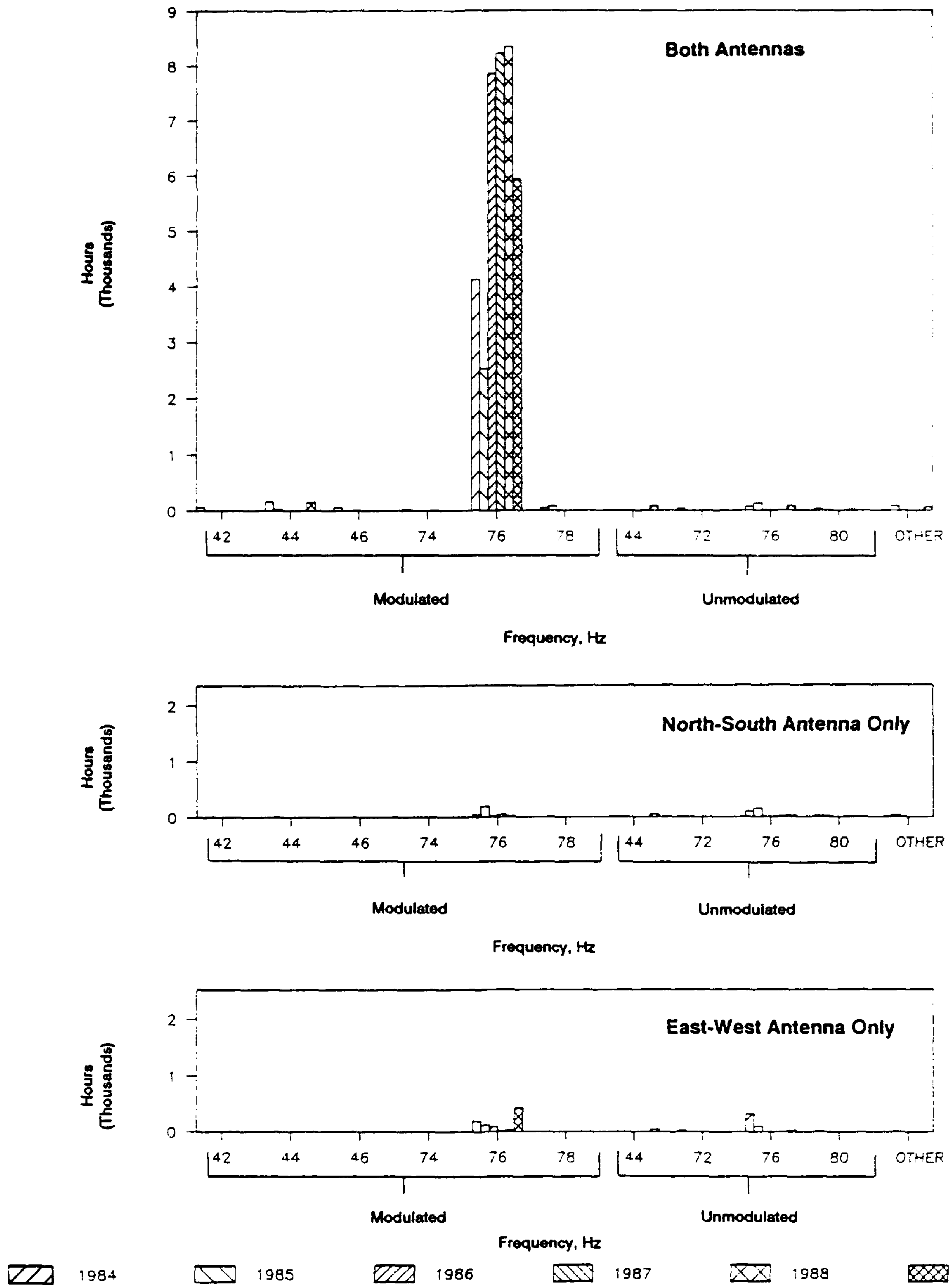


FIGURE 29. NRTF-CLAM LAKE OPERATING MODE SUMMARY, 1984-1989.

The pie charts in Figure 30 provide an annual operating summary by percentage of time per antenna in 1984-1989. They show nearly full-time operation of both antennas in 1986, 1987, and 1988, followed by a decrease in operating time in 1989.

NRTF-Clam Lake operations from 1984 through 1989 can be summarized as follows:

<u>1984</u>

- The NRTF-Clam Lake was transmitting about 60% of the time (about 5000 hr) (see Figures 28 and 30).
- About 81% of "on" time was with a modulated 76 Hz signal (see Figure 29).
- About 75% of "on" time was accrued in ~12 hr blocks of continuous operation each day.
- The remaining 25% of "on" time was in short, intermittent time periods, and accounted for most of the transmitter changes in operational mode.
- Less than 2.5% of total "on" time for both antennas was at a current level less than 290 amperes.

<u>1985</u>

- The NRTF-Clam Lake was transmitting about 40% of the time (about 3500 hr) (see Figures 28 and 30).
- About 81% of "on" time was with a modulated 76 Hz signal (see Figure 29).
- About 70% of "on" time was accrued in varying-length blocks of continuous operation each day.
- The remaining 30% of "on" time was in short, intermittent time periods, and accounted for most of the transmitter changes in operational mode.
- Less than 1.5% of total "on" time for both antennas was at a current level less than 290 amperes.

<u>1986</u>

- The NRTF-Clam Lake was transmitting about 91% of the time (about 8000 hr) (see Figures 28 and 30).
- About 99.8% of "on" time was with a modulated 76 Hz signal (see Figure 29).
- The transmitter was off weekly for a 4-hr scheduled maintenance period.
- The transmitter was off intermittently because of equipment failure or unscheduled maintenance.
- Less than 1% of total "on" time for both antennas was at a current level less than 290 amperes.

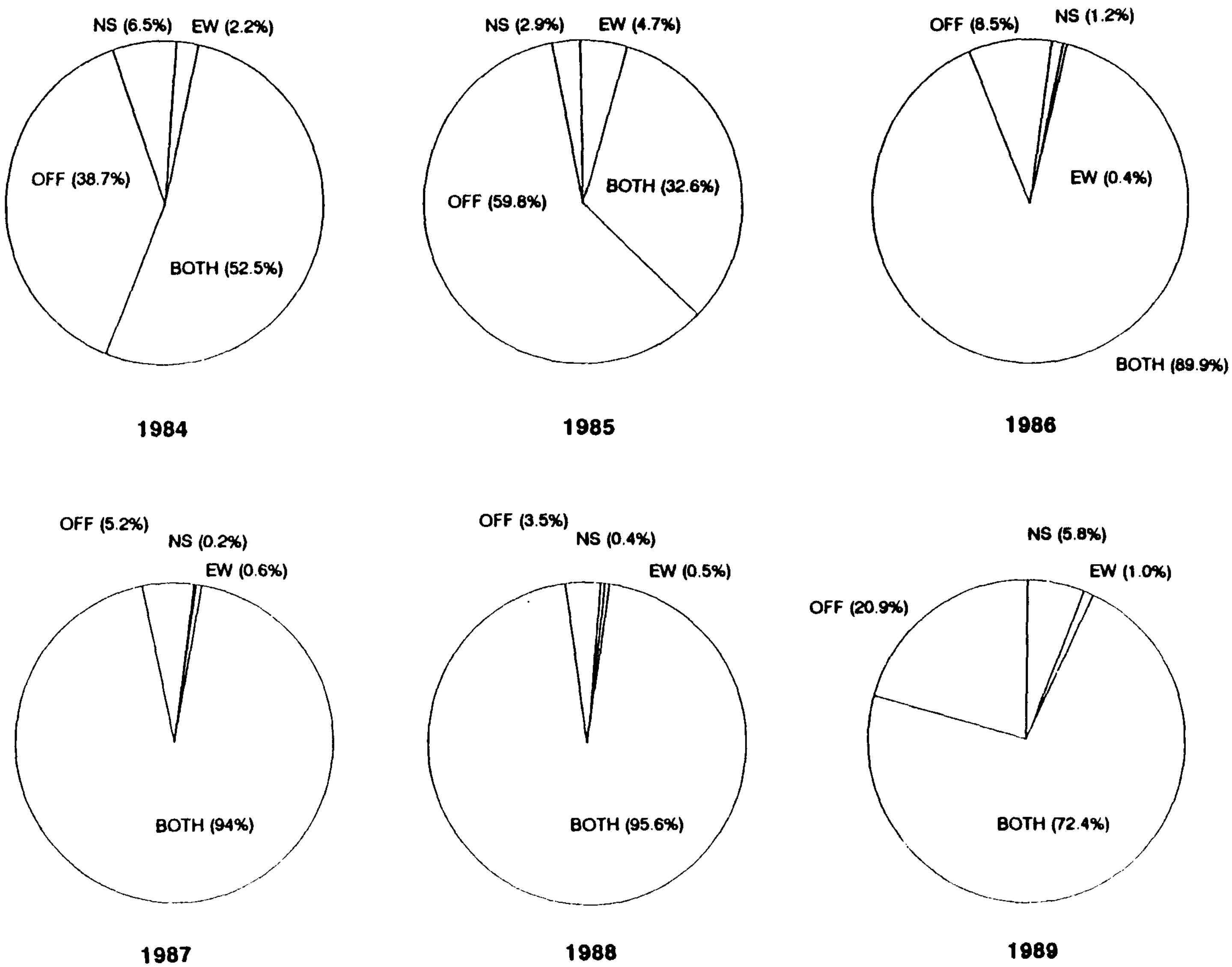


FIGURE 30. NRTF-CLAM LAKE OPERATING SUMMARY: PERCENTAGE OF TIME PER ANTENNA ELEMENT, 1984-1989.

1987

- The NRTF-Clam Lake was transmitting about 95% of the time (about 8300 hr) (see Figures 28 and 30).
- More than 99.9% of "on" time was with a modulated 76 Hz signal (see Figure 29).
- The transmitter was off weekly for a 4-hr scheduled maintenance period.
- The transmitter was off intermittently because of equipment failure or unscheduled maintenance (note maintenance period from 24 to 28 August).
- Less than 1% of total "on" time for both antennas was at a current level less than 300 amperes.

1988

- The NRTF-Clam Lake was transmitting about 96% of the time (about 8500 hr) (see Figures 28 and 30).
- Approximately 99.1% of "on" time was with a modulated 76 Hz signal (see Figure 29).
- The transmitter was off weekly for a 4-hr scheduled maintenance period during January through April, and for a 6-hr scheduled maintenance period during May through December.
- The transmitter was off intermittently because of unscheduled maintenance or testing.
- Less than 1% of total "on" time for both antennas was at a current level less than 300 amperes.

1989

- The NRTF-Clam Lake was transmitting about 79% of the time (about 6900 hr) (see Figures 28 and 30).
- Approximately 92% of "on" time was with a modulated 76 Hz signal (see Figure 29).
- The transmitter was off weekly for a 6-hr scheduled maintenance period.
- The transmitter was off intermittently because of unscheduled maintenance or testing.
- The transmitter was off for about 10 days in February for work on the remote tuning assembly network.
- The transmitter was off and the individual antennas were powered sporadically in the third quarter in support of special testing.
- The EW antenna was off from December 12 through the end of the year because of a transformer failure.
- About 1.2% of total "on" time was at a current level less than 300 amperes.

4.5.2.3 Summary of NRTF-Republic Operations, 1986-1989. The NRTF-Republic went through several stages of development, as did the NRTF-Clam Lake. These stages are marked by changes in the operating times, currents, and configurations of the NRTF-Republic. The antennas or antenna elements at the NRTF-Republic were first operated in March 1986. A low-current

(4, 6, or 10 ampere) unmodulated (continuous wave) signal was used, and the antennas or antenna elements were operated individually. In 1987, the antenna currents were increased to 15 amperes, and the NEW and SEW antenna elements constituted the EW antenna. Antenna currents were increased to 75 amperes during 1988, and in May of 1989, currents were increased to full power (150 amperes), the NS and EW antennas were operated simultaneously, a modulated signal was used, and operating times increased dramatically.

During the 15 and 75 ampere testing periods in 1987, 1988, and 1989, virtually all transmitter operations were conducted according to a 15-minute rotational schedule, referenced to quarter-hours as follows:

- 5 minutes--both elements off
- 5 minutes--NS antenna only on
- 5 minutes--EW element pair only on

NRTF-Republic operational logs supplied to IITRI list specific times at which such cycles begin and end. The actual operating times were estimated by assuming a 33% duty cycle for each antenna during the testing period. The rotational schedule was not used after 150 ampere testing began in May 1989.

Figures 31 and 32 show the hours of operation for each antenna or antenna element on a month-by-month basis. The hours of operation for 1986 are shown separately in Figure 31 because the NEW and SEW antenna elements were operated individually in 1986, rather than in parallel as in the following years. Figure 33 provides a bar graph of the annual operating summary of the NRTF-Republic by mode of operation for 1987-1989. As indicated, the predominant operating frequency was 76 Hz, although considerable testing was also performed at a 44 Hz frequency. The operating signal was normally unmodulated in 1987 and 1988, but predominantly modulated in 1989, as it will be in the future. In 1986, which does not appear in Figure 33, essentially all operation was with a 76 Hz unmodulated signal.

The pie charts in Figure 34 provide an annual operating summary by percentage of time per antenna or antenna element for 1986-1989. In 1986, the total "on" time was 1.8%; this time was split rather evenly among the NS antenna and the NEW and SEW antenna elements. In 1987, the total "on" time was 4.5%; this time was split evenly between the NS and EW antennas. In 1988, the total "on" time was 11.7%; this time was split evenly between the NS and EW antennas. In 1989, the total "on" time was 58%; both the NS and EW antennas operated simultaneously for the majority (91.8%) of this "on" time.

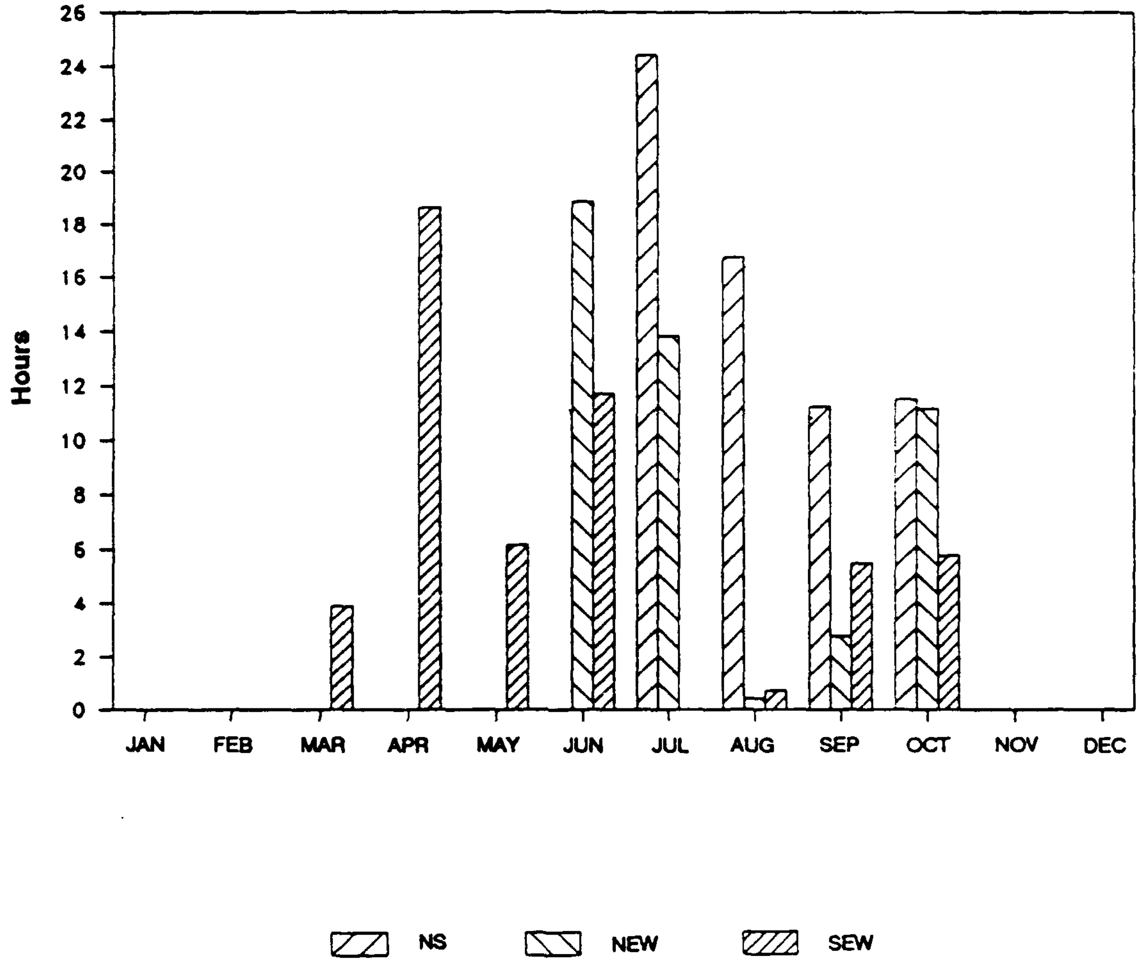


FIGURE 31. NRTF-REPUBLIC MONTHLY OPERATING SUMMARY, 1986.

60297/790

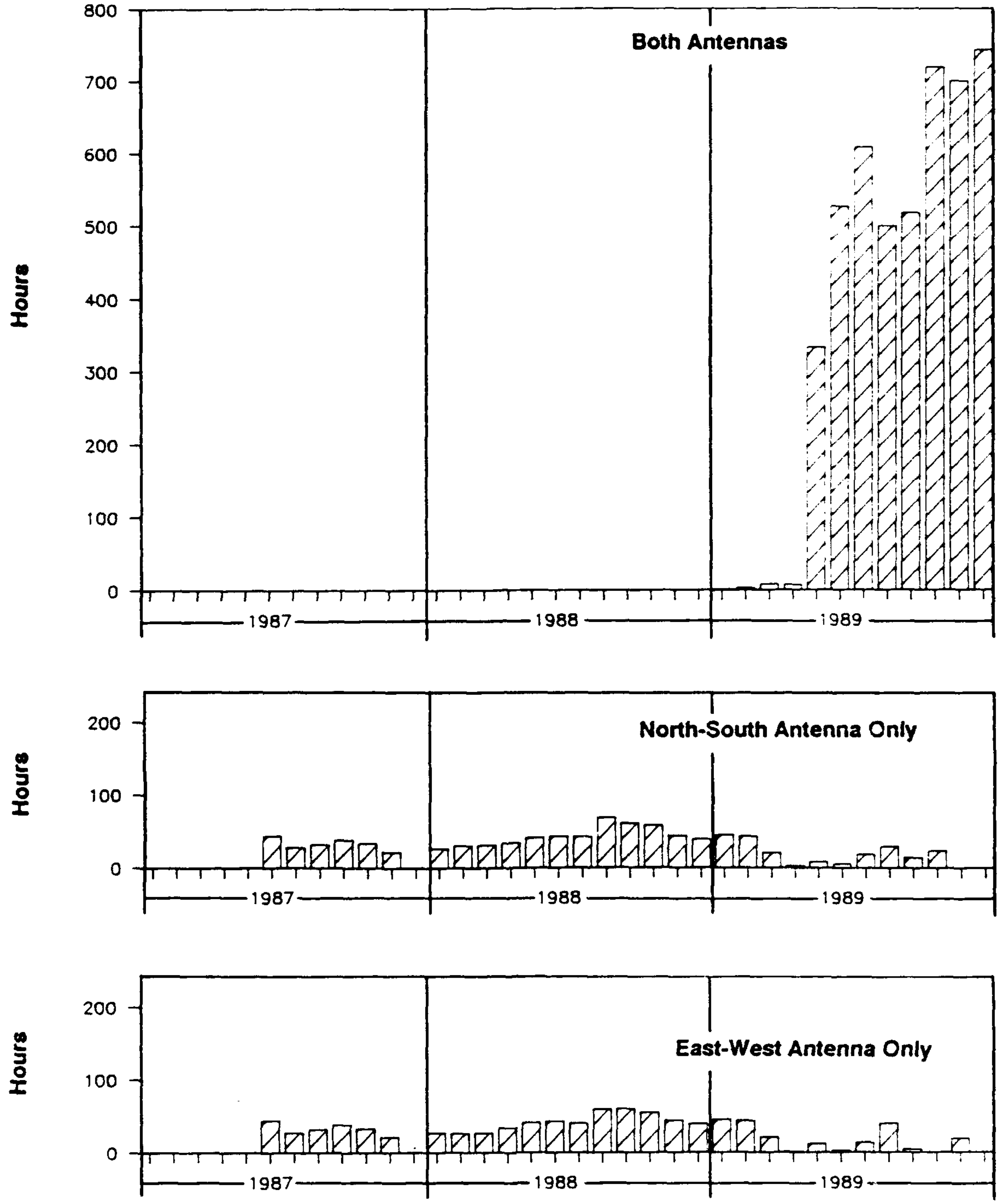


FIGURE 32. NRTF-REPUBLIC MONTHLY OPERATING SUMMARY, 1987-1989.

60297/790

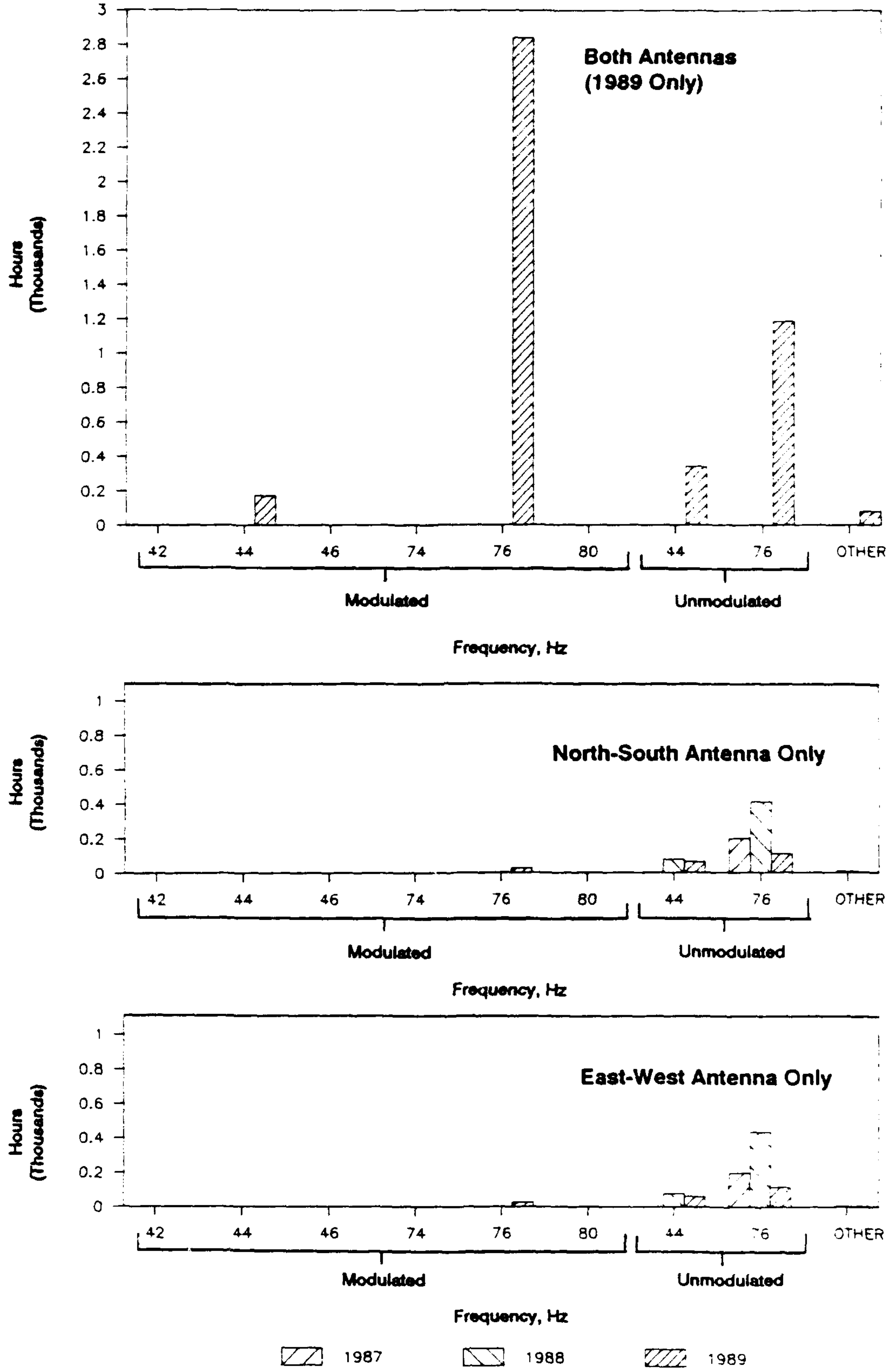


FIGURE 33. NRTF-REPUBLIC OPERATING MODE SUMMARY, 1987-1989.

60297/790

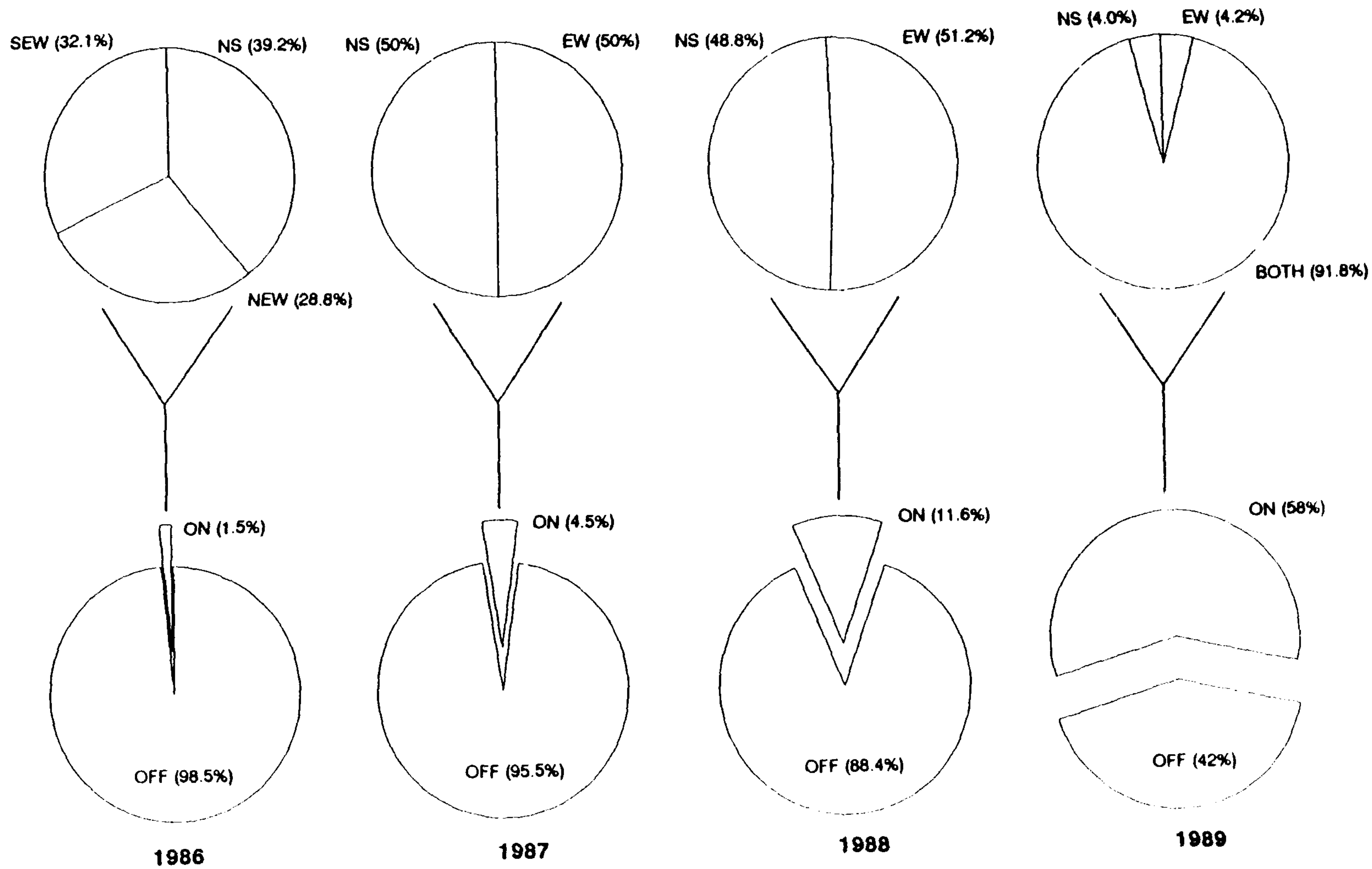


FIGURE 34. NRTF-REPUBLIC OPERATING SUMMARY: PERCENTAGE OF TIME PER ANTENNA ELEMENT, 1986-1989.

NRTF-Republic operations in 1986-1989 can be summarized as follows:

1986

- The NRTF-Republic was transmitting about 1.8% of the time (about 160 hr) (see Figures 31 and 34).
- About 98% of "on" time was with a continuous wave 76 Hz signal.
- The NS antenna and the NEW and SEW antenna elements were operated individually.
- Primary operating currents were 4 and 6 amperes for the NS antenna and the NEW antenna element, respectively, and both 6 and 10 amperes for the SEW antenna element.

1987

- The NRTF-Republic was transmitting about 4.6% of the time (about 400 hr) (see Figures 32 and 34).
- 100% of "on" time was with a continuous wave 76 Hz signal.
- The NS and EW antennas were operated individually.
- 99.6% of the operating time was with a 15 ampere current.

1988

- The NRTF-Republic was transmitting about 11.6% of the time (about 1000 hr) (see Figures 32 and 34).
- About 98% of "on" time was with a continuous wave 76 Hz or 44 Hz signal.
- The NS and EW antennas were operated individually.
- Primary operating currents were 15 and 75 amperes. 40.6% of "on" time was at 15 amperes, and 59.2% of "on" time was at 75 amperes.

1989

- The NRTF-Republic was transmitting about 58% of the time (about 5100 hr) (see Figures 32 and 34).
- About 57% of "on" time was with a modulated 76 Hz signal, and 28% of "on" time was with an unmodulated 76 Hz signal (see Figure 33).
- The NS and EW antennas were operated simultaneously for 91.8% of the "on" time.
- Primary operating currents were 75 and 150 amperes. 95% of "on" time was at 150 amperes.

5. CONCLUSIONS AND DISCUSSION

Annual EM field measurement surveys in support of the Ecological Monitoring Program were performed during February, May, August, September, and October of 1989. Measurements were made at a total of 218 points at 61 study sites in Wisconsin and Michigan, compared with 194 points at 60 sites in 1988. New measurement points in 1989 include five at the laboratory of the small mammals and nesting birds studies, four at the laboratory of the native bees studies, 13 at the upland flora and soil microflora treatment study sites, and two at the aquatic ecosystems study sites. Most points were added in order to better characterize spatial EM field variability at sites or to measure at special field sources, e.g., where a 138 kV transmission line crosses the Ford River.

Special testing conducted at the NRTF-Clam Lake during IITRI's annual EM measurement survey in Wisconsin in 1989 allowed for a more comprehensive measurement protocol than in prior years. The 1989 measurement protocol was unique in that it allowed for 60 Hz measurements at all points for the first time since 1985, and 44 Hz measurements at all points for the first time ever.

The NRTF-Republic began operation with a 76 Hz, 150 ampere antenna current during 1989, and EM field measurements were made under these conditions for the first time. The 1989 measurement protocol in Michigan allowed for 76 Hz EM field measurements at all points under either modulated or unmodulated transmission. Measurements were made of the ambient 60 Hz EM fields at treatment study sites only if both antennas were off or if their signal was unmodulated. At the control study sites, 60 Hz measurements were made regardless of antenna condition. 60 Hz EM field measurements could not be made at treatment sites during modulated signal operation of the NRTF-Republic.

EM field measurements are being conducted in the laboratories of all researchers whose protocols require that they remove study species from the field for laboratory measurements and then return the species to the field. The small mammals and nesting birds studies, native bee studies, and soil amoeba studies include such protocols. Laboratory measurements were made in the laboratories of the former two studies in 1988 and 1989, and similar measurements will be made in the laboratory of the soil amoeba studies in 1990.

At the laboratory of the small mammals and nesting birds studies, the 60 Hz air electric fields and magnetic fields were found to be high relative to the EM fields at the study sites. Measures were taken to reduce the air electric fields by shielding and by equipment grounding. Magnetic fields at the metabolic testing bath, where they were the highest, were reduced with Mumetal shields. This mitigation reduced the air electric fields by factors of 4.5 to 20 and the magnetic fields by factors of 30 to 68. At the laboratory of the native bees studies, the 60 Hz air

electric fields at work areas were also high relative to the EM fields at the study sites. Wire-mesh shield cages were built and installed at principal work areas and at a holding area. Measurements showed these shields to be effective in reducing the air electric fields by a factor of as much as 100.

Data loggers were designed, fabricated, and installed at the soil amoeba study sites in July 1988. The data loggers record electrical exposure parameters of the culture cells as well as the soil temperature and earth electric fields at the study sites. Culture cell measurements document changes in cell exposures as the cultures grow and soil parameters change with moisture and temperature.

Seasonal variations of the earth electric field are of concern to study investigators whose biota remain on a study site throughout the year. Variations are expected to be greater near ground terminals than near antenna elements. The variations are being continuously monitored near both a ground terminal and an antenna element, using the data loggers set up for the soil amoeba studies. At the end of each biological field study season, the logger programs are changed to measure only the earth electric fields throughout the fall, winter, and spring months to provide information on the seasonal variability of the longitudinal electric field. Data loggers have remained on the study sites since their installation in 1988, except for a period in the first quarter of 1989 when they were removed for maintenance and modifications. Data collection using this equipment is expected to continue throughout the course of the study.

Researchers for the upland flora studies have noted a faster aspen growth rate at the treatment site over that at the control site that appears to correspond to yearly increases in antenna current. They wish to perform further tests for a correlation between EM field intensities and aspen growth rate by comparing the growth rates for individual trees at the treatment site with the actual field intensity at each tree. A detailed characterization of the spatial variability of EM fields at the treatment study sites is important for evaluating this possibility as well as other possible related effects. which As a first step in this characterization, measurement points were added at the treatment study sites in 1989 to define EM field intensity profiles perpendicular to the antenna and ground elements that bisect these sites. The earth electric field profile at the antenna site shows unexpected variability, and more extensive spatial and temporal measurements are planned for 1990.

Ratios of 76 Hz EM fields were recalculated for the aquatic ecosystems treatment and control study site pairs using the newly obtained 150 ampere measurement data. As predicted early in the study, not all of the study site pairs met the guidelines discussed in Section 1.3 of this report. Refinement of activity locations within study sites was suggested to the researchers in order to improve the ratios of prime concern. The addition of a fyke net between the NS antenna and a 138 kV transmission line was suggested for the fish movement studies. This would allow

discrimination between possible effects from these two EM field sources on fish movement behavior.

In 1988, variations of the longitudinal electric field intensities and magnetic flux densities along the centerlines of both a treatment and a control study transect for the bird species and communities studies in Wisconsin were characterized by making several measurements along the length of each transect. In 1989, similar measurements were made along the remaining four treatment transects in Wisconsin. The measurements show considerable EM field variation along the treatment transects, but there is no overlap in field intensities between treatment and control transects. Similar characterizations are planned for Michigan study transects in 1990.

The slime mold studies and the wetlands studies concluded their field data collection in Wisconsin in 1987. The bird species and communities studies, which began later, concluded their data collection in Wisconsin in 1989. All Ecological Monitoring Program studies in Wisconsin are now complete, and no additional EM field measurements are planned in the NRTF-Clam Lake area.

In 1990, the NRTF-Republic is expected to operate both antennas simultaneously with a 150 ampere MSK signal, as it did for much of 1989. IITRI plans to remeasure all points characterized in 1989. Measurement protocols to be used in 1990 will be determined by the actual antenna status at the time. Data logger monitoring of the soil amoeba study sites will continue in 1990, and data loggers and/or fixed probes are being considered for installation at the upland flora and soil microflora study sites.

6. REFERENCES

1. Enk, J. O.; Gauger, J. R. ELF Communications System Ecological Monitoring Program: Measurement of ELF Electromagnetic Fields for Site Selection and Characterization--1983. IIT Research Institute, Technical Report E06549-10, 19 pp. plus appendixes, 1985.

2. Brosh, R. M.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Measurement of ELF Electromagnetic Fields for Site Selection and Characterization--1984. IIT Research Institute, Technical Report E06549-14, 37 pp. plus appendixes, 1985.

3. Brosh, R. M.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1985. IIT Research Institute, Technical Report E06549-24, 48 pp. plus appendixes, 1986.

4. Haradem, D. P.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1986. IIT Research Institute, Technical Report E06549-37, 52 pp. plus appendixes, 1987.

5. Haradem, D. P.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1987. IIT Research Institute, Technical Report E06595-1, 54 pp. plus appendixes, 1988.

6. Haradem, D. P.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1988. IIT Research Institute, Technical Report E06595-5, 69 pp. plus appendixes, 1989.

7. ELF Communications System Ecological Monitoring Program: Slime Mold Studies--Final Report. IIT Research Institute, Technical Report E06620-3, January 1990, 83 pp.

8. ELF Communications System Ecological Monitoring Program: Wetland Studies--Final Report. IIT Research Institute, Technical Report E06620-2, November 1989, 250 pp.

APPENDIX A

SMALL MAMMALS AND NESTING BIRDS STUDIES

SMALL MAMMALS AND NESTING BIRDS STUDIES

During February, September, and October, 1989, IITRI field crews made ELF electromagnetic (EM) field measurements at 69 measurement points at a total of five treatment sites, four control sites, three (bird) displacement sites, the Crystal Falls laboratory site, and the remote holding facility where the study animals are kept prior to being examined in the laboratory. The measurement regime differed in 1989 from 1988 in that one measurement point (1L1-1) was dropped and five measurement points (1L1-5 through -9) were added at the Crystal Falls laboratory site. One additional measurement point (1L1-10) was added at the Crystal Falls laboratory site in 1990. (The 1990 laboratory measurement data are included in this appendix because they support the 1989 mitigation efforts discussed in Section 4.1.1 of this report and were available at the time the report was compiled.)

The positions of all sites relative to the NRTF-Republic are shown on the composite map in Figure A-1. The site numbers listed on the map are those used by IITRI. Table A-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are shown in Figures A-2 through A-16.

The small mammals and nesting birds studies monitor parental care, nestling growth and maturation, fecundity, homing, activity patterns, embryological development, and metabolic physiology. The electric and magnetic fields in the air are considered important factors to be examined in orientation and other behavior patterns of birds. The electric and magnetic fields in the earth near the surface are important to the small mammals studies.

EM field measurements for 1989 and previous years are found in Tables A-2 through A-7. Tables A-2, A-3, and A-4 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables A-5, A-6, and A-7 present 76 Hz data for these three fields at the corresponding operating currents of the NRTF-Republic for each year. 60 Hz data for the transverse electric field and magnetic flux density measured in the Crystal Falls laboratory in 1989 and 1990 appear in Tables A-8 and A-9, respectively.

The 60 Hz EM field measurement data tables for 1983 through 1989 include data for 21 measurement locations that are no longer active. This has been done in order to provide historical measurement values at study sites where new measurement locations were laid out after antenna construction in 1986. Plots of the 60 Hz EM field profiles for the five nest box sites for the years 1987 through 1989 are presented in Figures A-17 through A-23. The year-to-year changes in the 60 Hz field magnitudes illustrated in these figures reflect variations in the level of power line coupling to the NRTF-Republic antennas.

The 60 Hz EM fields measured at the study sites in 1989 are consistent with those measured in previous years. The 60 Hz field intensities at the Crystal Falls laboratory are typically 100 times greater than those at the study sites, and are of the same order of magnitude as the 76 Hz intensities at the treatment sites. IITRI made efforts to reduce the ambient field levels in critical laboratory work areas by recommending methods for shielding sources of electric fields and by providing magnetic shielding for the containers used for metabolic testing.

Magnetic and air electric field shielding in the Crystal Falls laboratory was discussed in Section 4.1.1 of this report. Table A-8 presents 60 Hz air electric field data before and after shielding was implemented in the Crystal Falls laboratory. It can be seen from this table that the air electric field shielding reduced the fields by factors of 4.5 to 20.

Figure A-38 shows the Mumetal shields used to reduce the magnetic field exposure intensities during metabolic tests. The effectiveness of the shielding is seen in Table A-9, which gives the magnetic flux densities inside the test containers under three different shielding configurations. The final shielding configuration served to reduce the unshielded magnetic fields by factors of 30 to 68.

The 1989, 76 Hz measurements were made with 150 ampere antenna currents, the predominant operating current of the NRTF-Republic since 4 May 1989. The EM exposures at the study sites for the period prior to 4 May can be estimated either by using the 75 ampere antenna current measurement data from 1988 or by using one-half the value of the 1989 150 ampere data.

Plots of the 76 Hz EM field profiles for the five nest box test sites for the years 1987 through 1989 are presented in Figures A-24 through A-37. The annual increases in field magnitudes illustrated by these profiles reflect the level of antenna current at the time of measurement: 15 amperes in 1987, 75 amperes in 1988, and 150 amperes in 1989. The EM field exposures at any nest box can be estimated from the appropriate EM profile, given the nest box distance to the antenna wire.

EM field measurements were made at the release points for the Cleveland Homestead, North Turner Road, and Panola Plains tree swallow homing transects. The EM field environment along the flight paths can be estimated using Figures A-39 and A-40, which show the locations of the bird flight paths and the ELF antenna relative to positions of high-voltage 60 Hz transmission lines and 60 Hz power distribution lines, respectively. The EM fields generated by the distribution lines are of magnitudes similar to those that are generated by the ELF antenna when operating at full power. The EM fields produced by the transmission lines can be considerably higher, depending on operating conditions. The transverse electric field generated by a transmission line may be as much as 100 times greater than that of the ELF antenna. The magnetic flux generated by a transmission line is dependent on the load current, and may be several times greater than that of the ELF antenna.

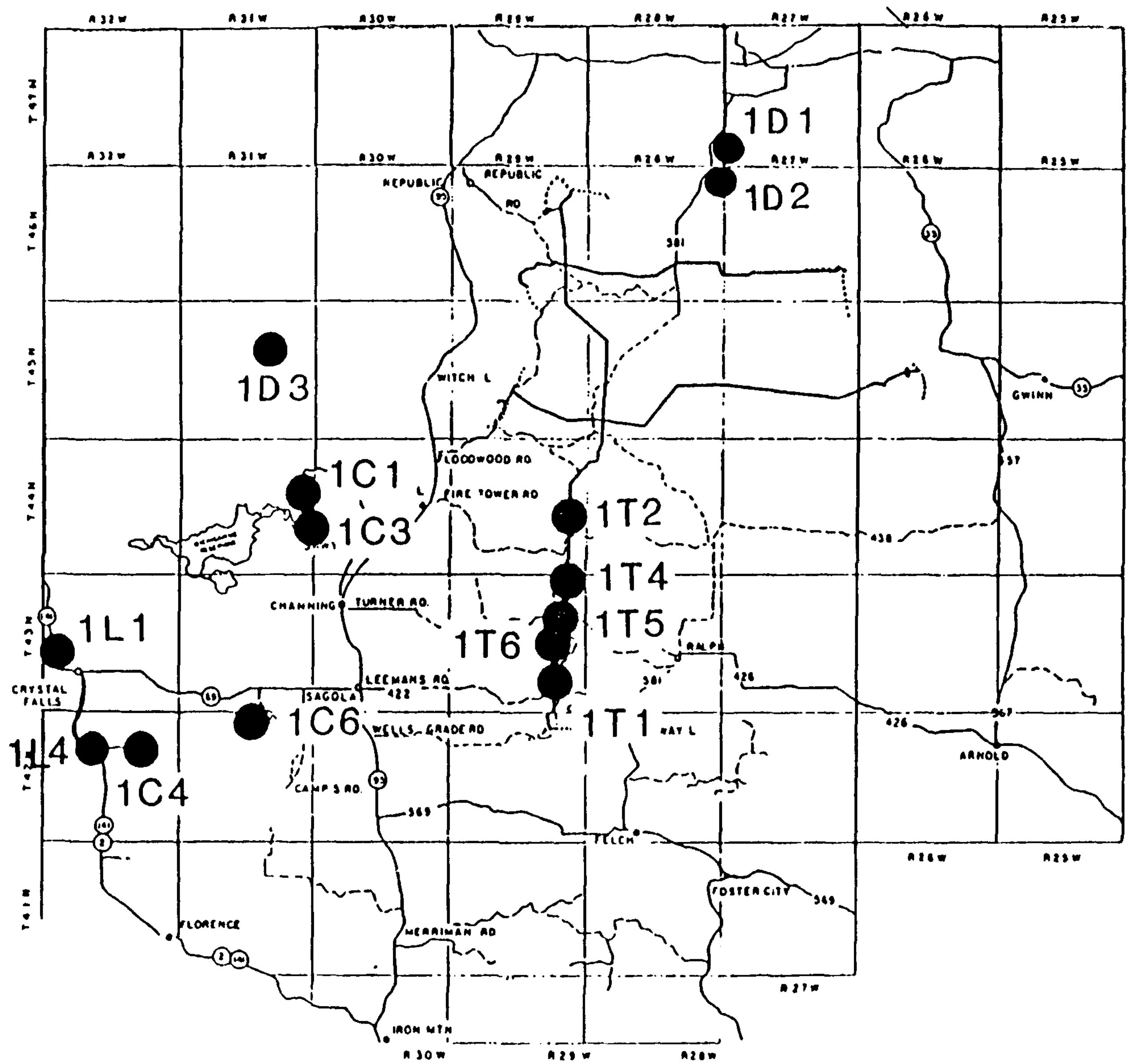


FIGURE A-1. POSITIONS OF SMALL MAMMALS AND NESTING BIRDS STUDY SITES RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

TABLE A-1. SITE NO. CROSS-REFERENCE
Small Mammals and Nesting Birds Studies

IITRI Site No.	Investigator's Site Name	Location		
		Township	Range	Section(s)
1T1	Pirlot Road	T43N	R29W	23, 26
1T2	Cleveland Homestead	T44N	R29W	25
1T4	North Turner Road	T43N	R29W	1
1T5	Ford River North	T43N	R29W	14
1T6	Ford River South	T43N	R29W	14
1C1	Michigamme North	T44N	R31W	13
1C3	Michigamme South	T44N	R31W	24
1C4	Panola Plains	T42N	R32W	10
1C6	Tachycineta Meadow	T42N	R31W	3
1D1	Cleveland Homestead Displacement	T47N	R28W	36
1D2	North Turner Displacement	T46N	R28W	12
1D3	Panola Plains Displacement	T45N	R31W	14
1L1	Crystal Falls Laboratory	T43N	R32W	29
1L4	Remote Holding Facility	T42N	R32W	9

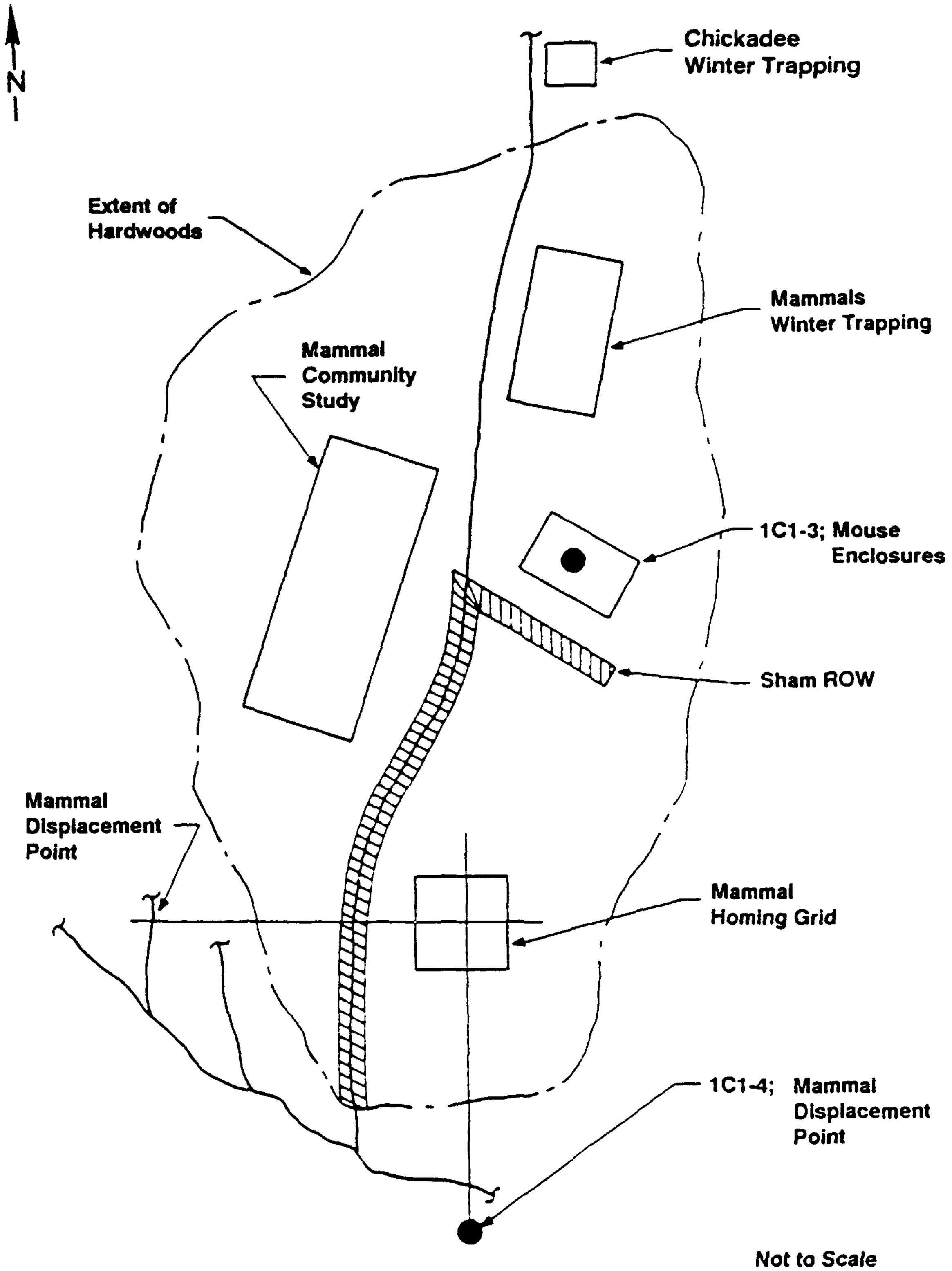


FIGURE A-2. MEASUREMENT POINTS AT MICHIGAMME NORTH; 1C1-3, 4.

60297/190

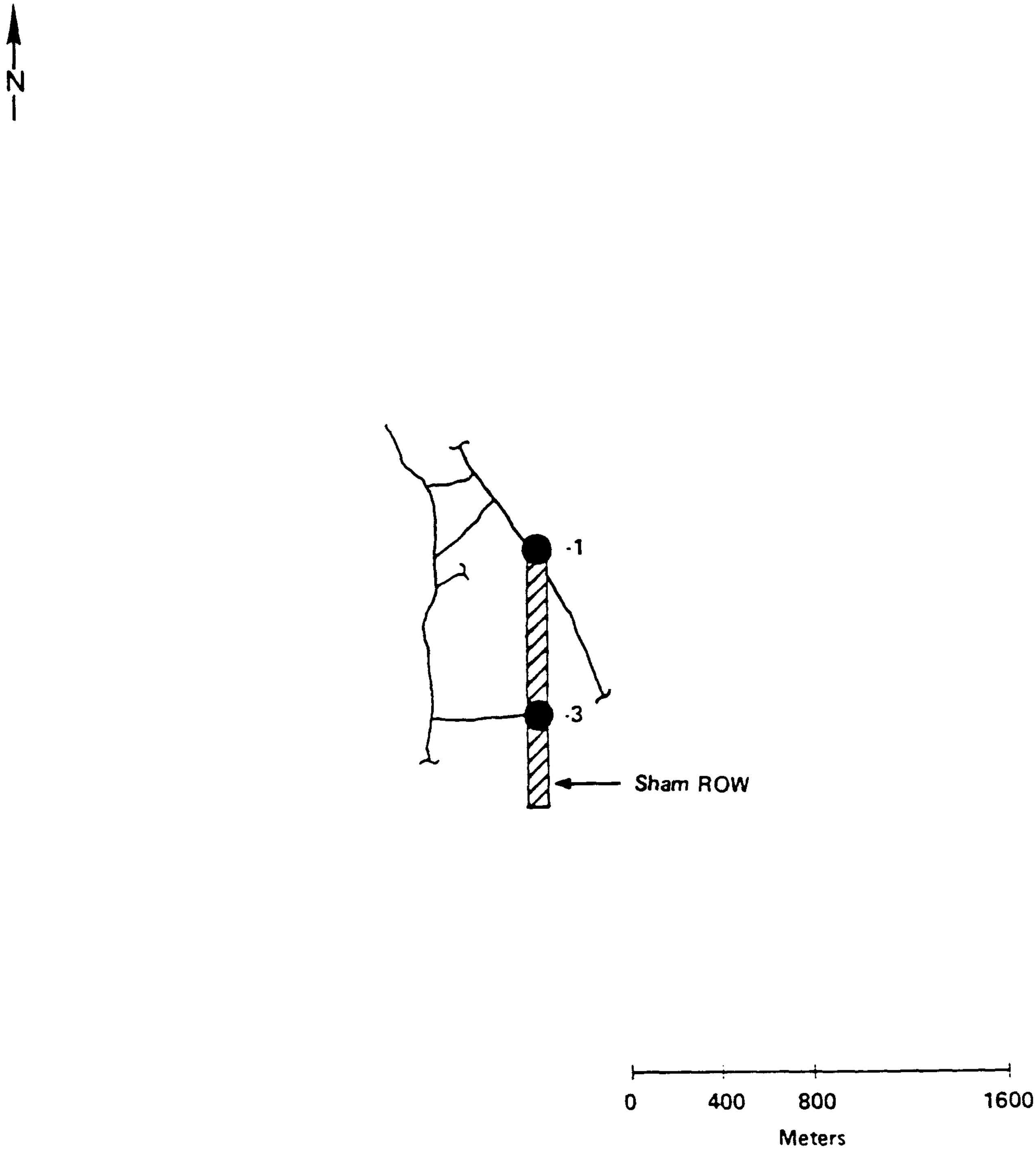


FIGURE A-3. MEASUREMENT POINTS AT MICHIGAMME SOUTH; 1C3-1, 3.

60297/190

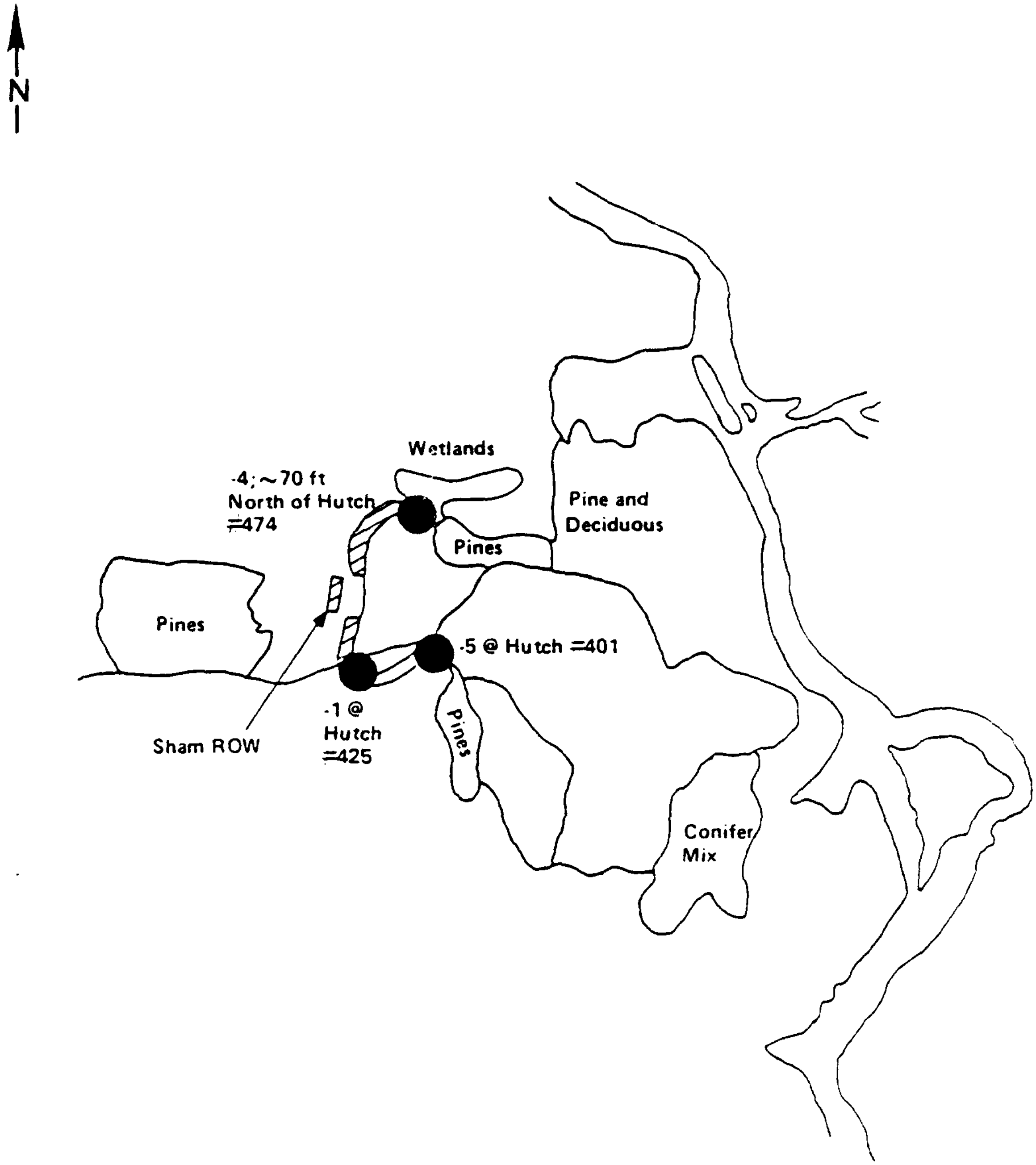


FIGURE A-4. MEASUREMENT POINTS AT PANOLA PLAINS; 1C4-1, 4, 5.

60297/790

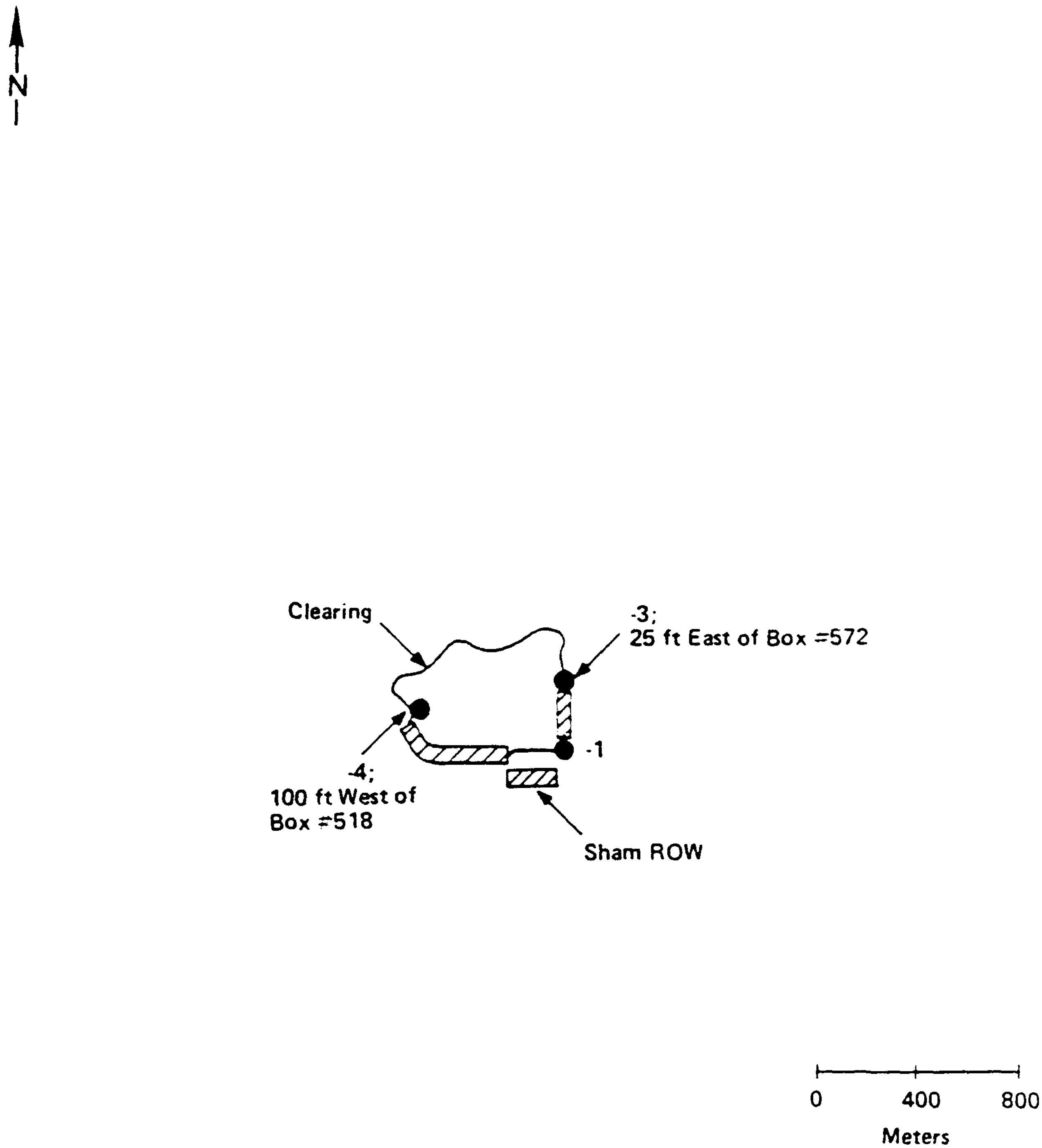


FIGURE A-5. MEASUREMENT POINTS AT TACHYCINETA MEADOW; 1C6-1, 3, 4.

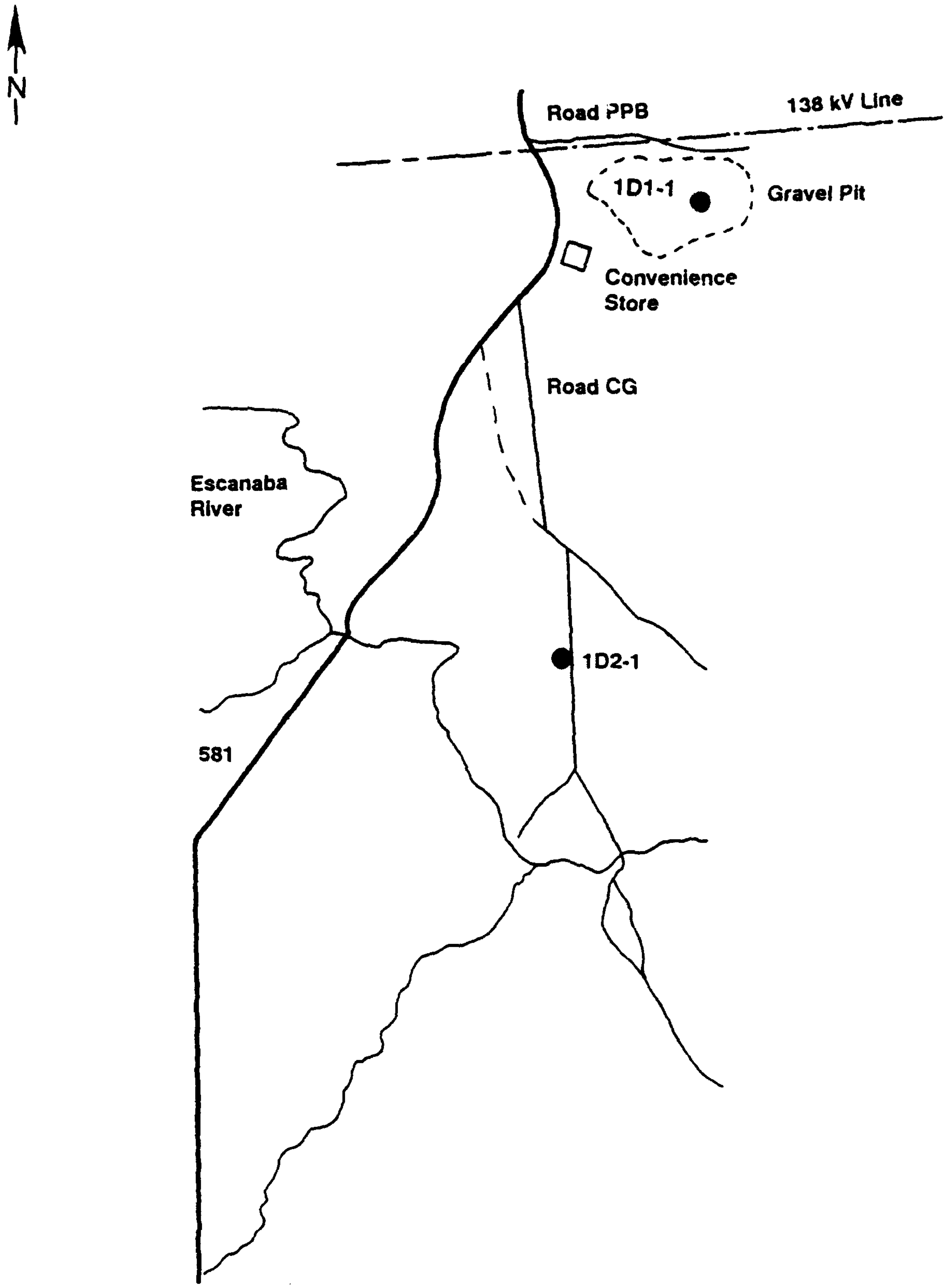


FIGURE A-6. MEASUREMENT POINTS AT CLEVELAND HOMESTEAD AND NORTH TURNER ROAD DISPLACEMENT POINTS; 1D1-1 AND 1D2-1.

60297/790

60297/790

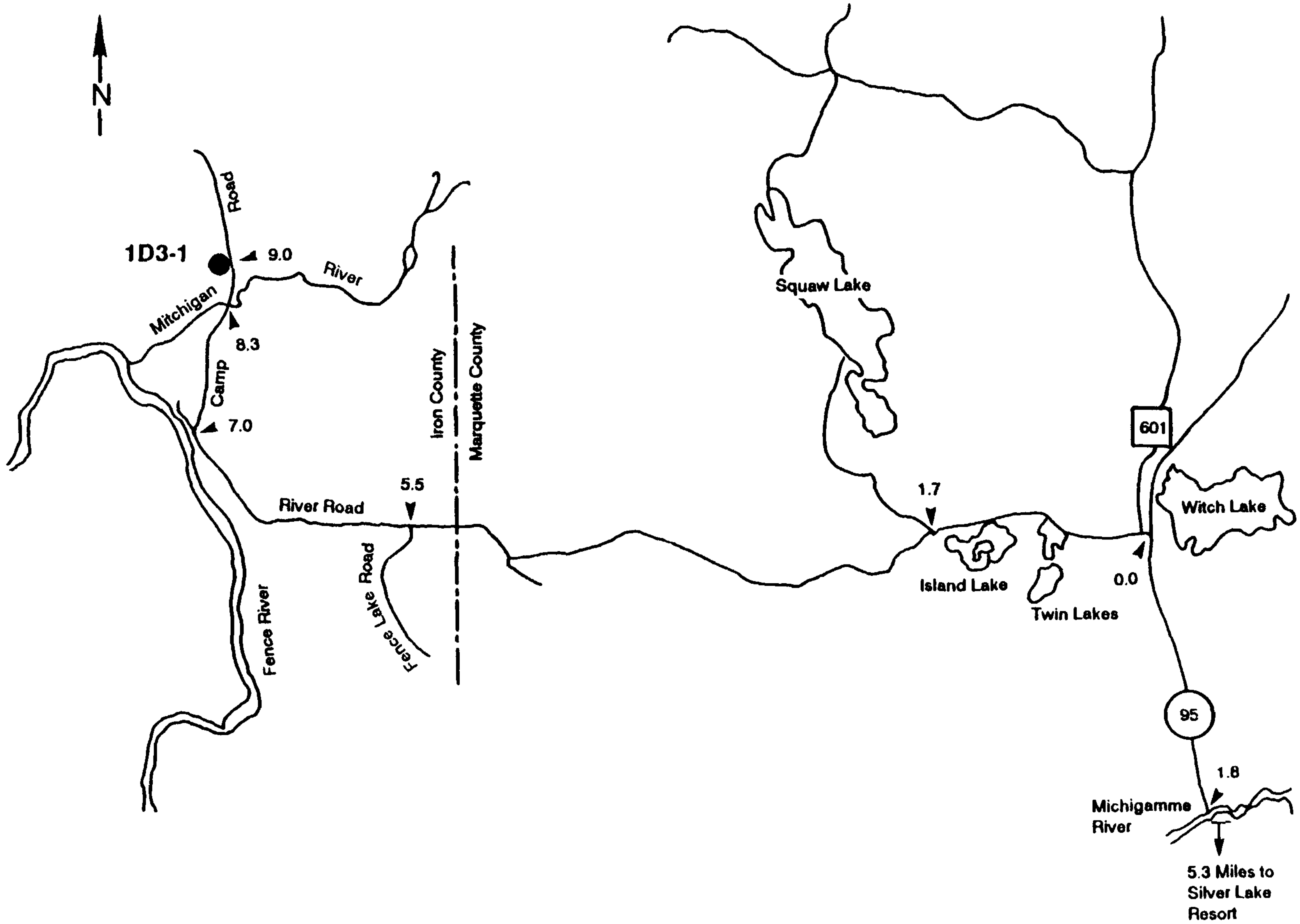


FIGURE A-7. MEASUREMENT POINT AT PANOLA PLAINS DISPLACEMENT; 1D3-1.

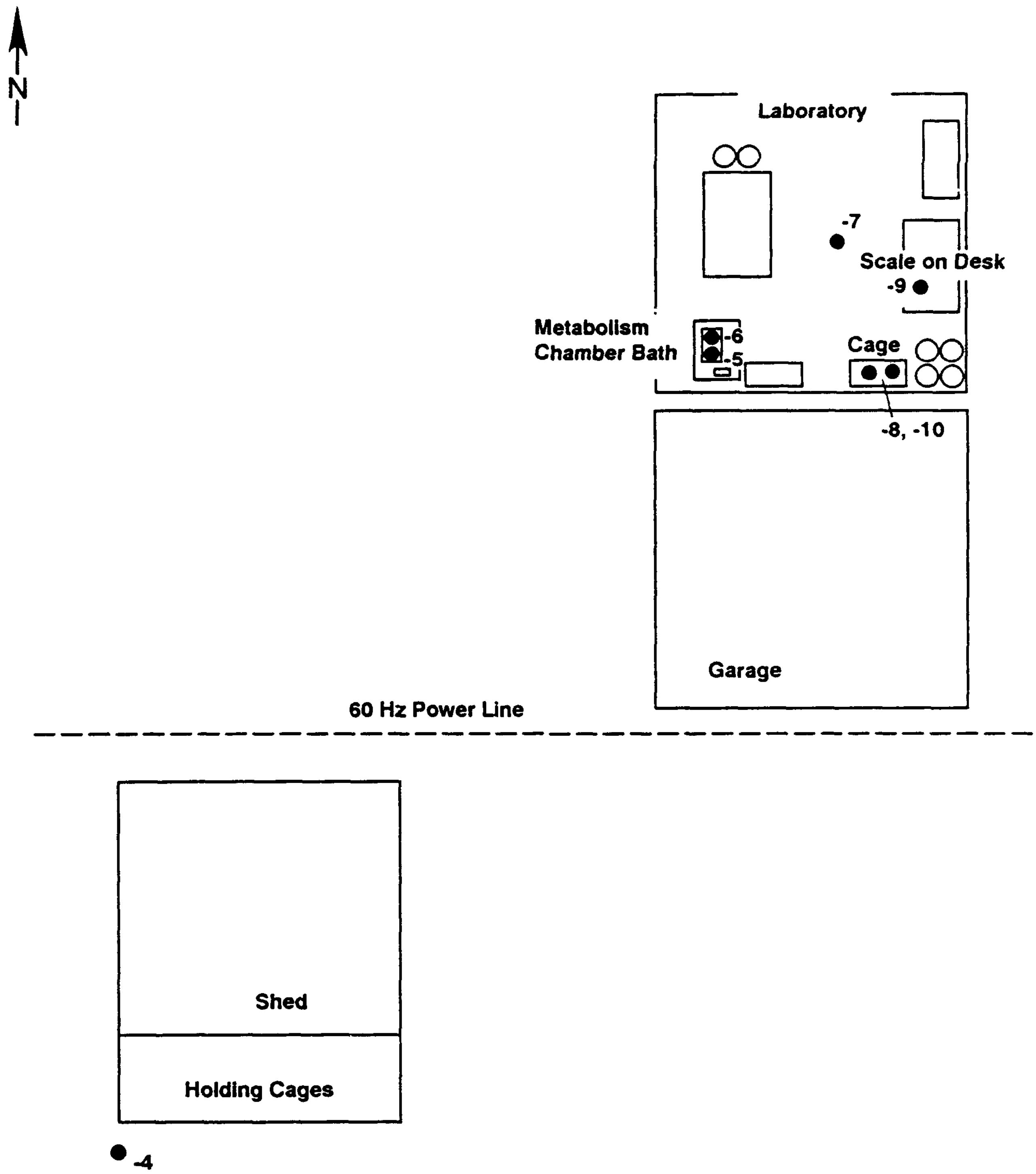


FIGURE A-8. MEASUREMENT POINTS AT MAMMAL LABORATORY; 1L1-4 THROUGH 1L1-10.

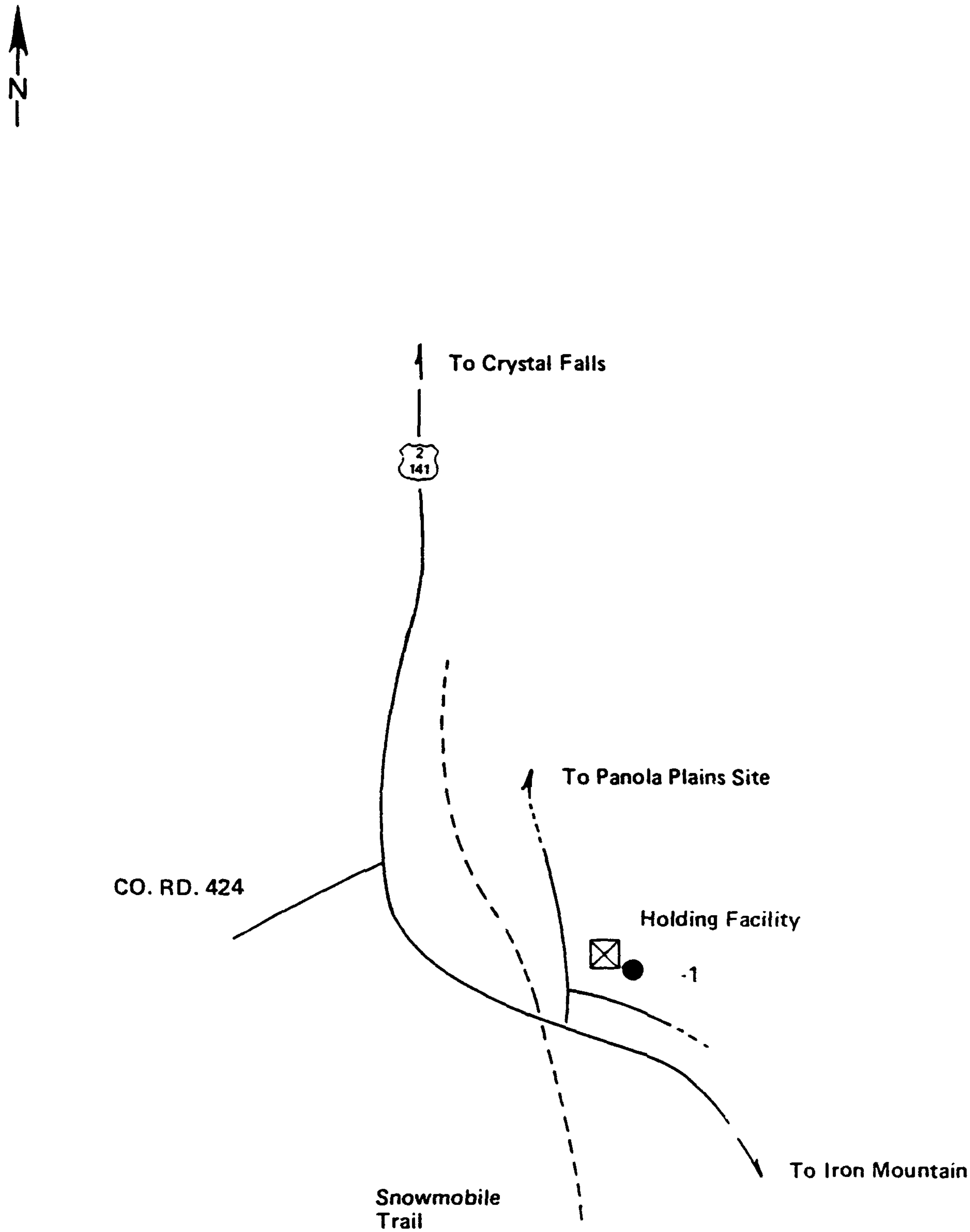


FIGURE A-9. MEASUREMENT POINT AT REMOTE HOLDING FACILITY; 1L4-1.

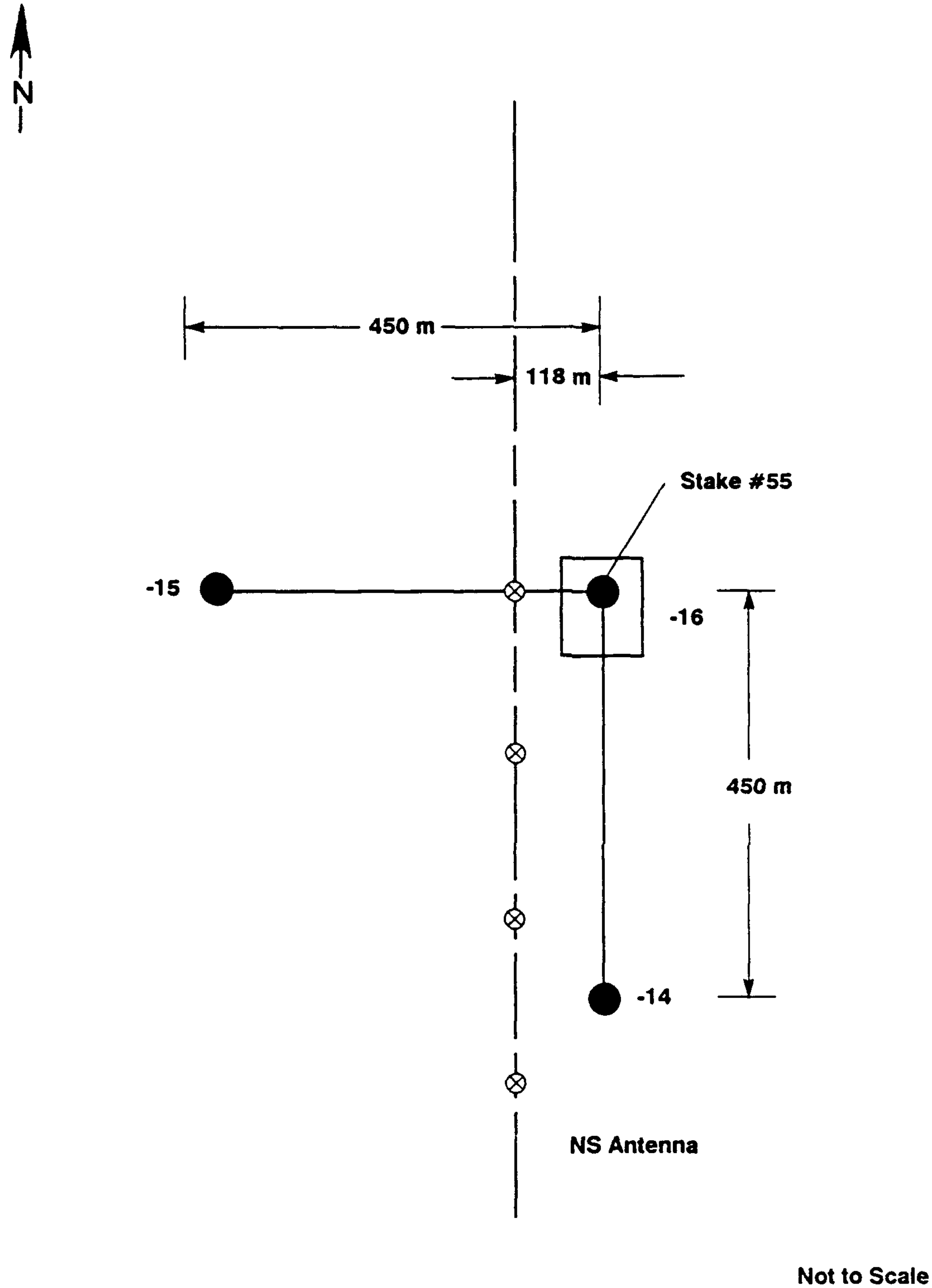


FIGURE A-10. MEASUREMENT POINTS AT PIRLOT ROAD MAMMAL DISPLACEMENT; 1T1-14, 15, 16.

60297/190

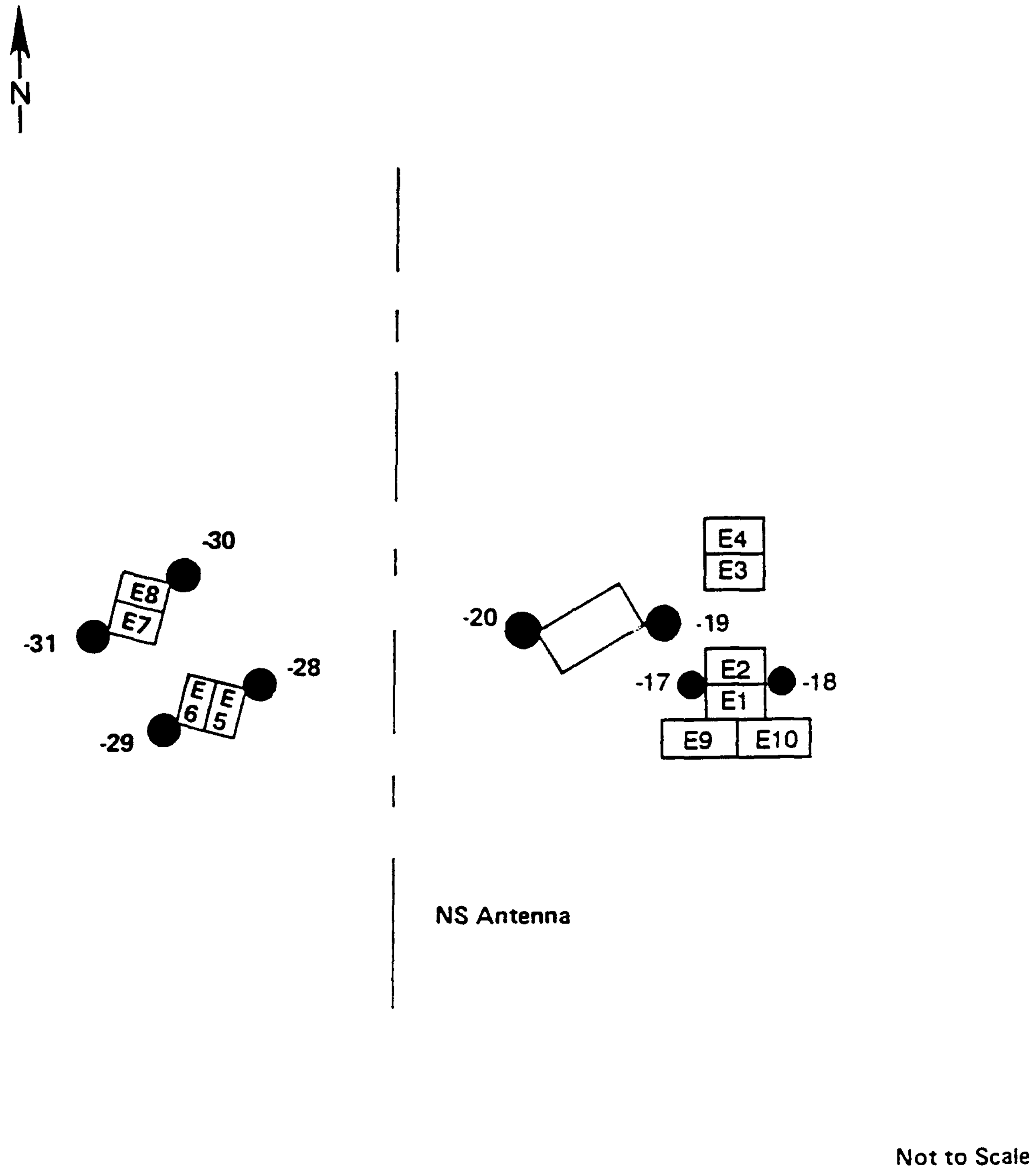


FIGURE A-11. MEASUREMENT POINTS AT PIRLOT ROAD MOUSE ENCLOSURES; 1T1-17 THROUGH 20, 28 THROUGH 31.

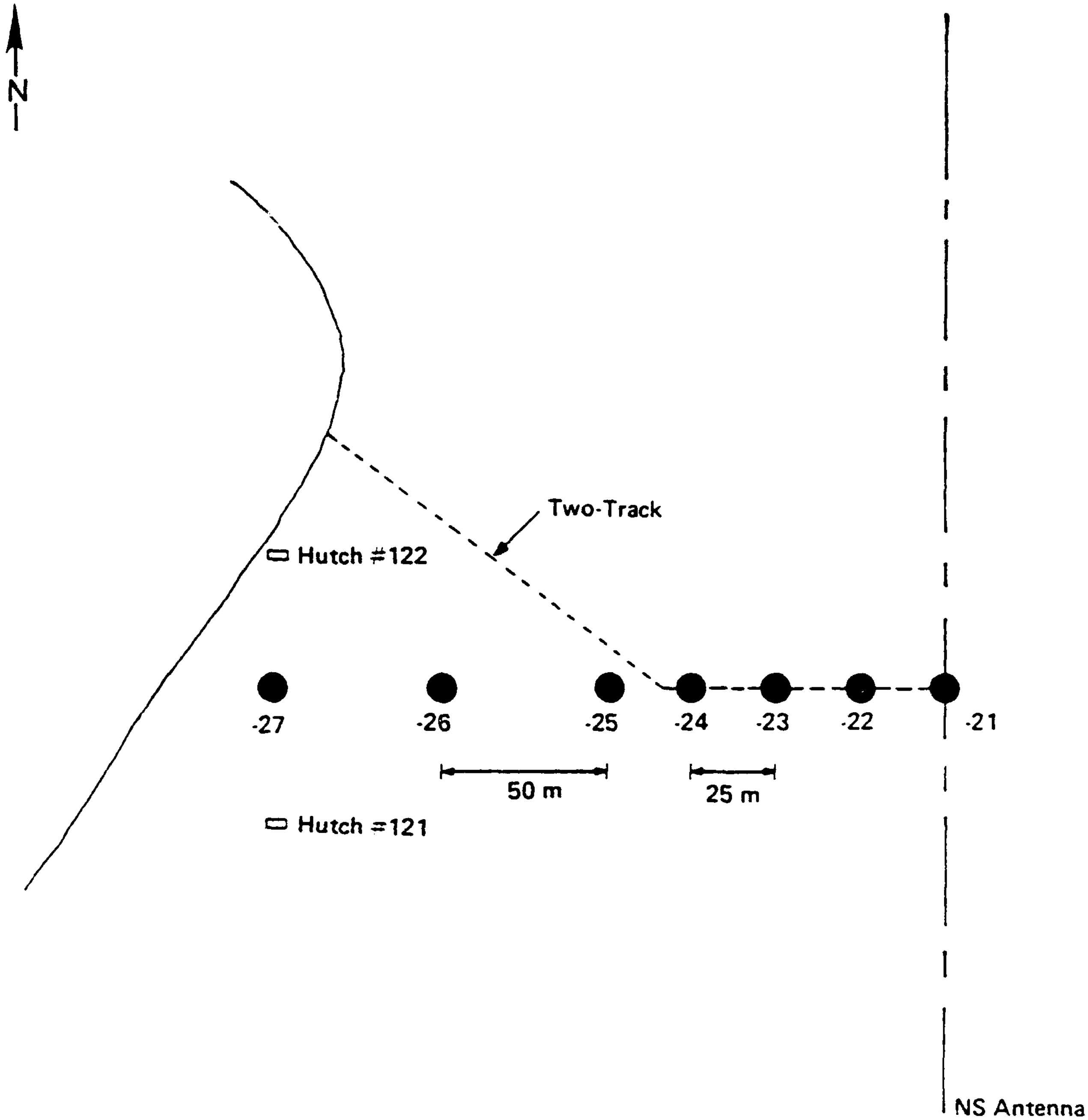


FIGURE A-12. MEASUREMENT POINTS AT PIRLOT ROAD NEST BOXES; 1T1-21 THROUGH 27.

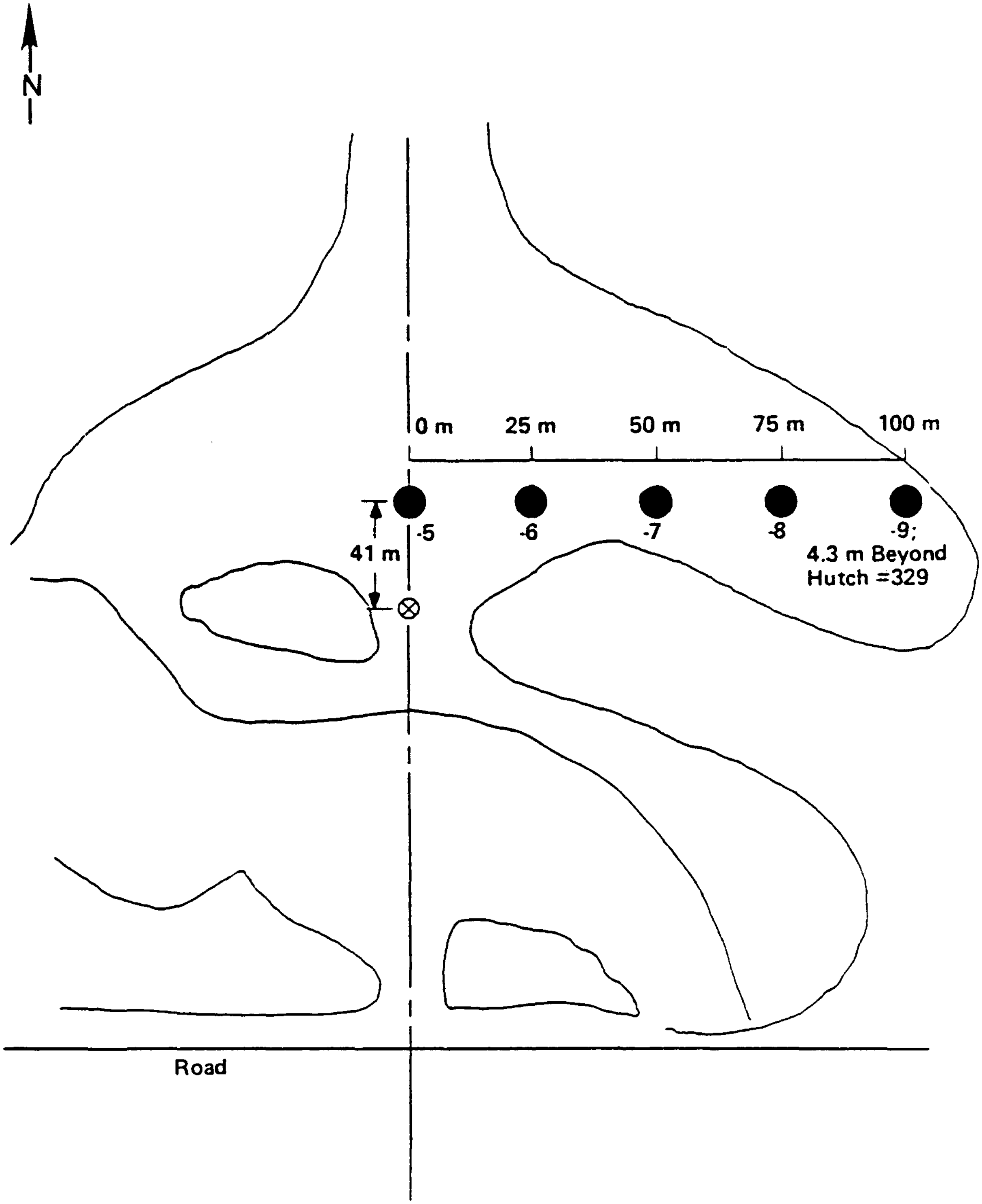


FIGURE A-13. MEASUREMENT POINTS AT CLEVELAND HOMESTEAD; 1T2-5 THROUGH 9.

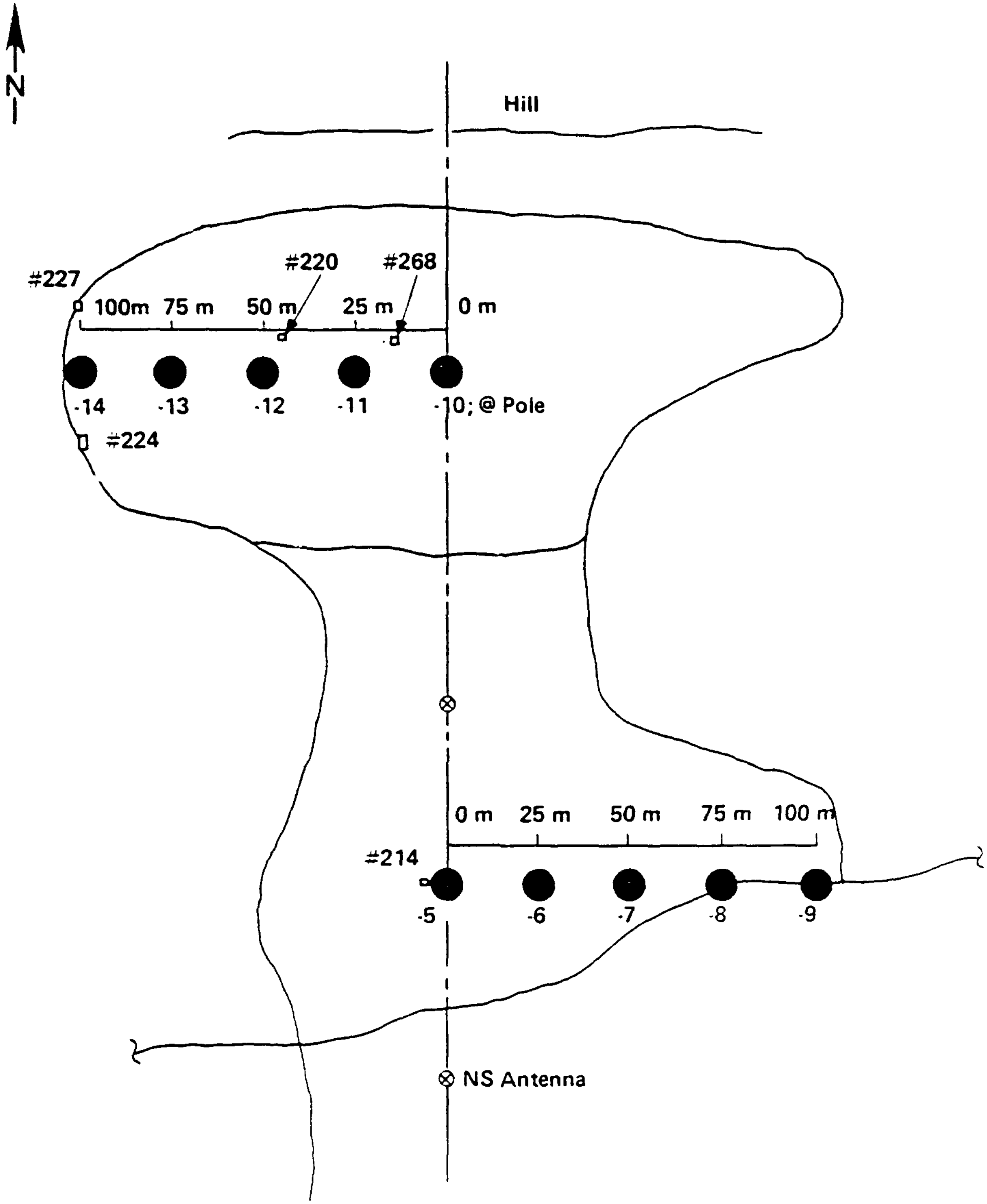


FIGURE A-14. MEASUREMENT POINTS AT NORTH TURNER ROAD; 1T4-5 THROUGH 14.

60297/790

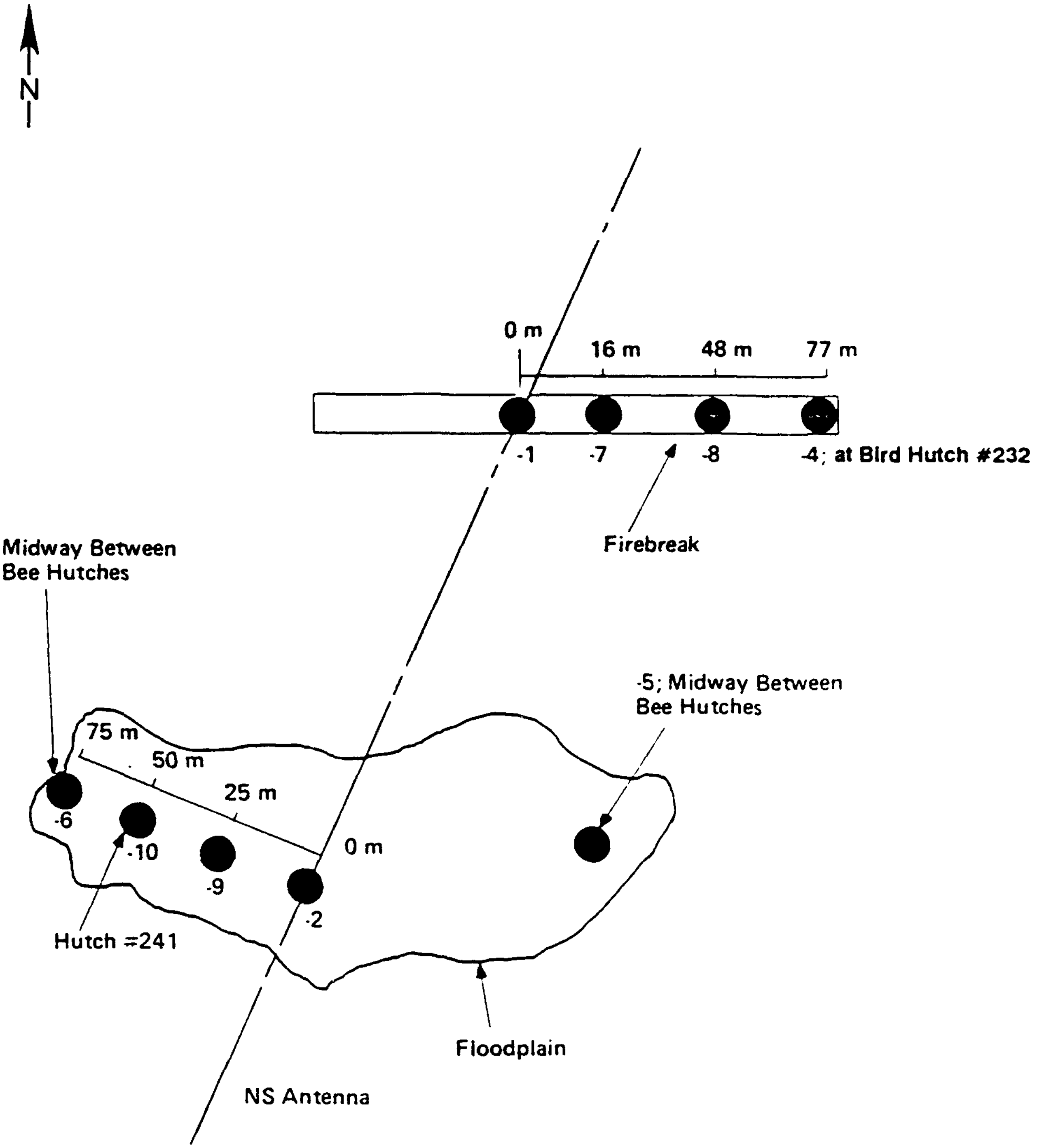


FIGURE A-15. MEASUREMENT POINTS AT FORD RIVER NORTH; 1T5-1, 2, 4, 6, 7, 8, 9, 10.

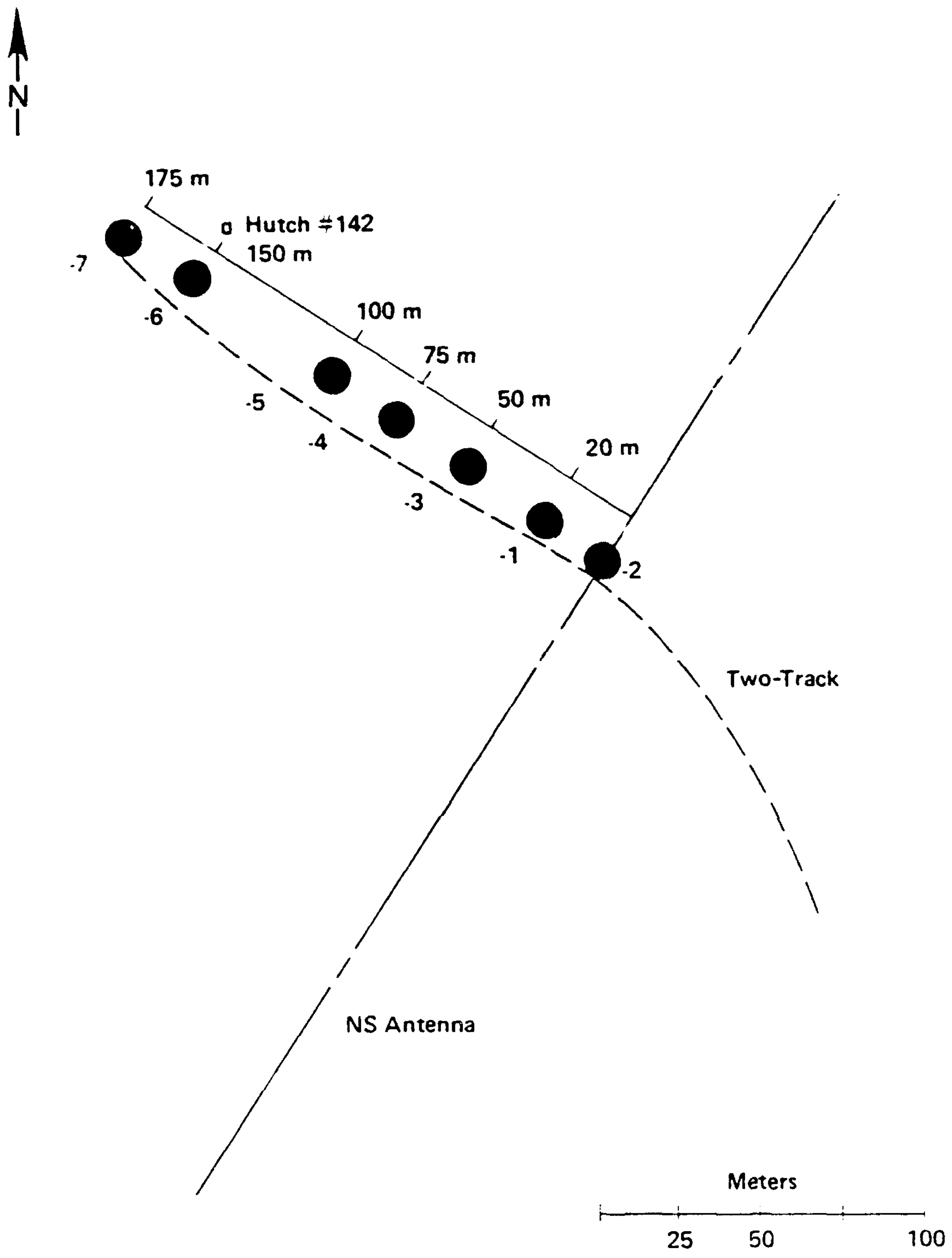


FIGURE A-16. MEASUREMENT POINTS AT FORD RIVER SOUTH NEST BOXES; 1T6-1 THROUGH 7.

60297/190

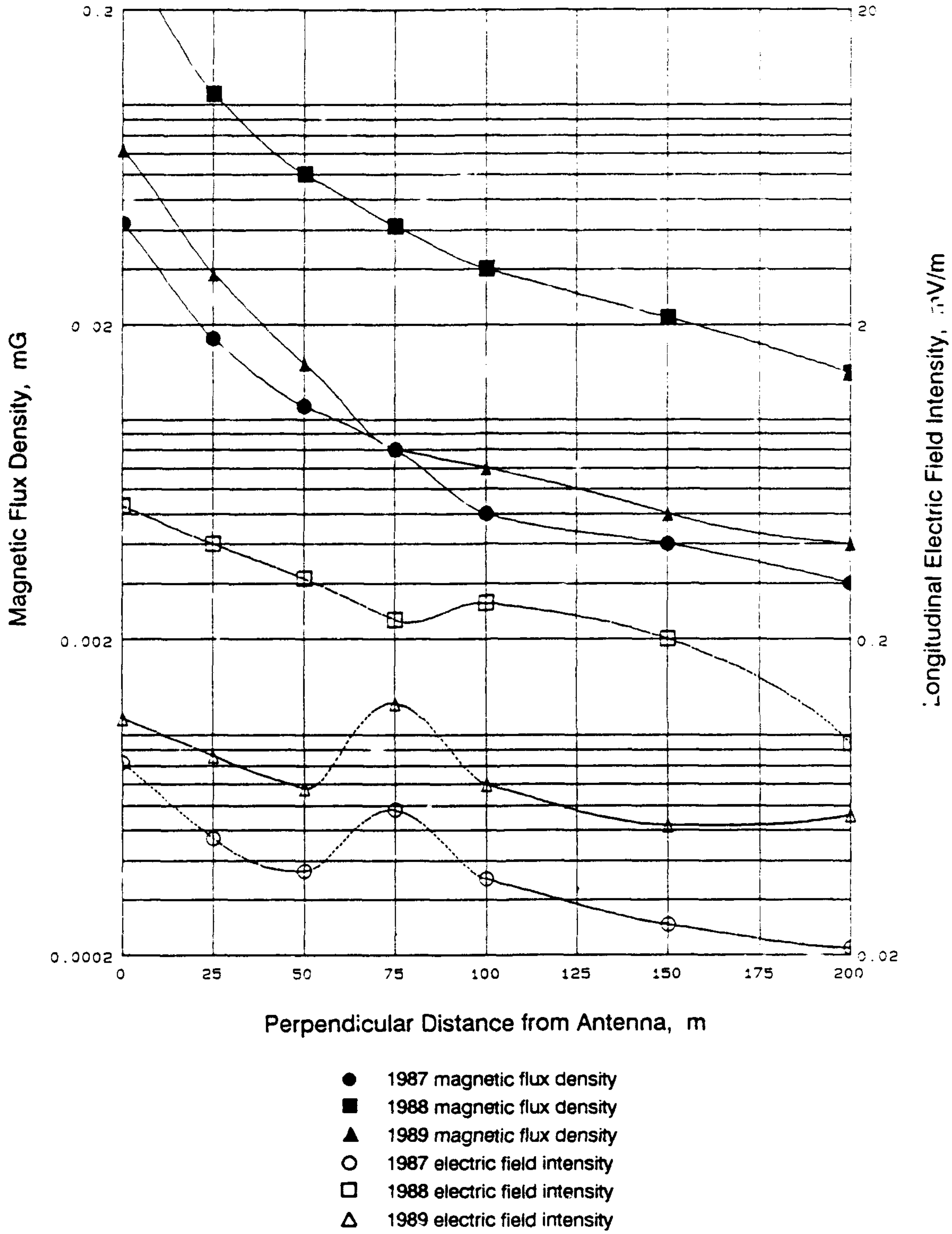


FIGURE A-17. 60 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD PROFILES, PIRLOT ROAD; 1T1-21 THROUGH 27.

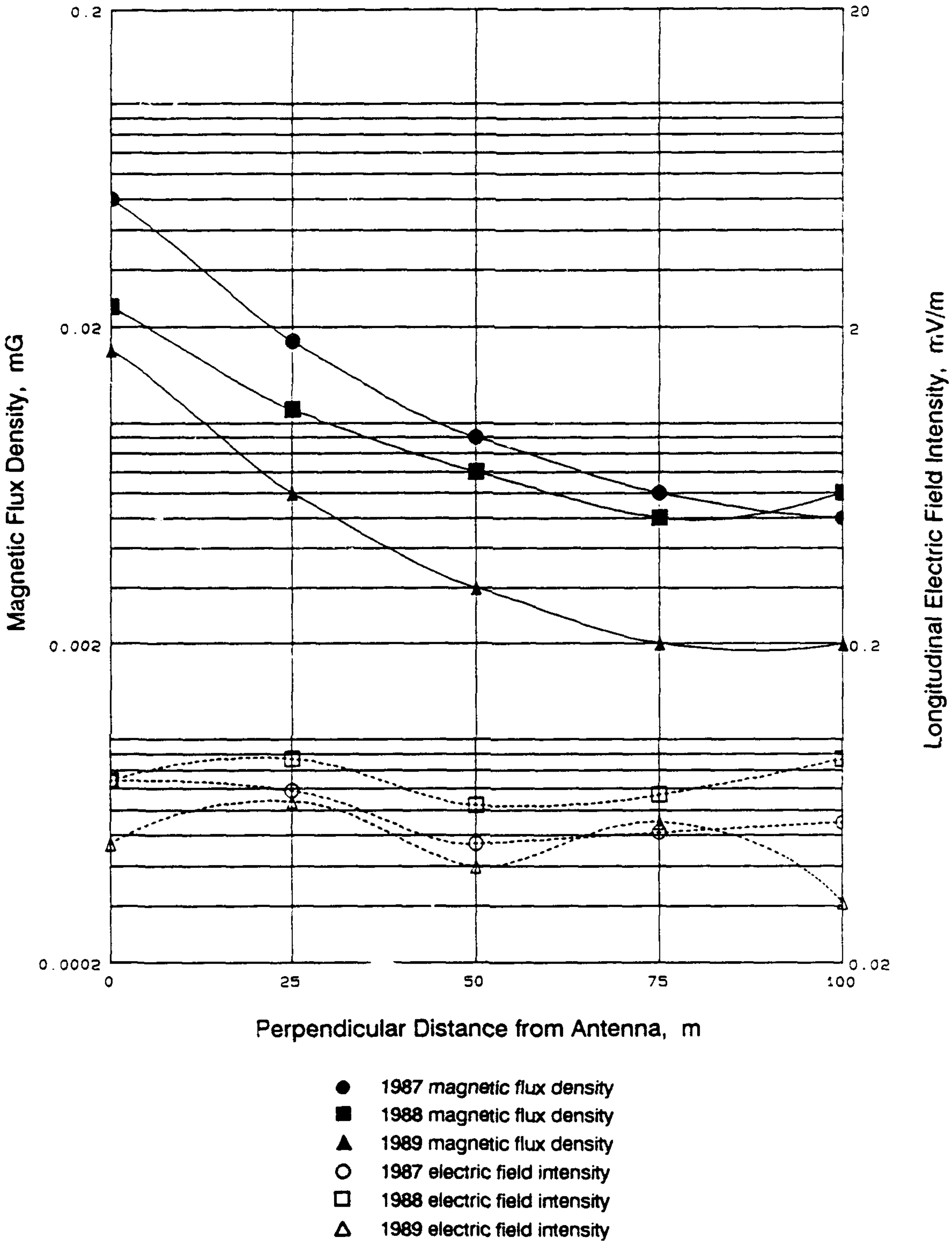


FIGURE A-18. 60 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD PROFILES, CLEVELAND HOMESTEAD; 1T2-5 THROUGH 9.

60297/790

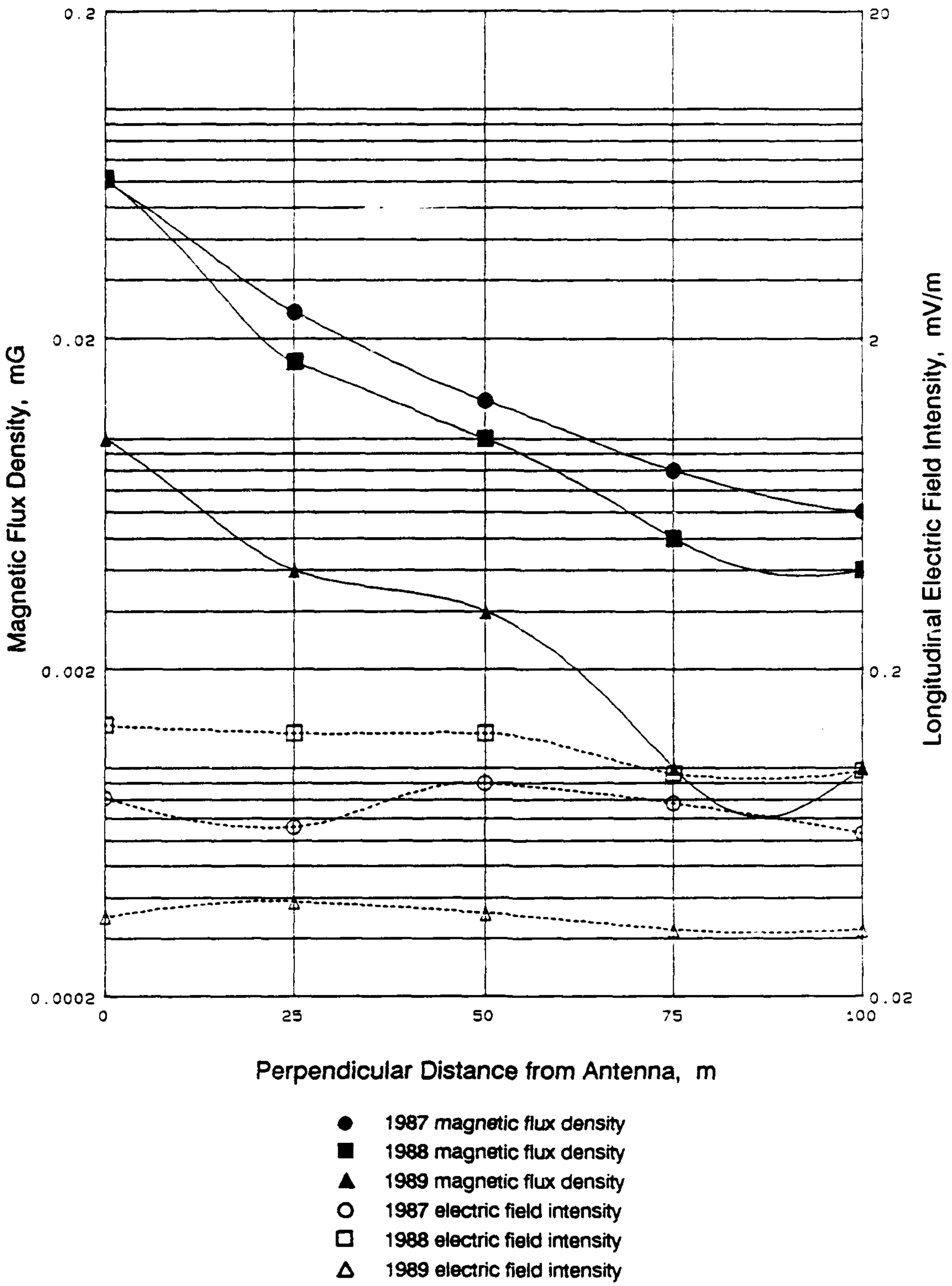


FIGURE A-19. 60 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD PROFILES, NORTH TURNER ROAD; 1T4-5 THROUGH 9.

60297/790

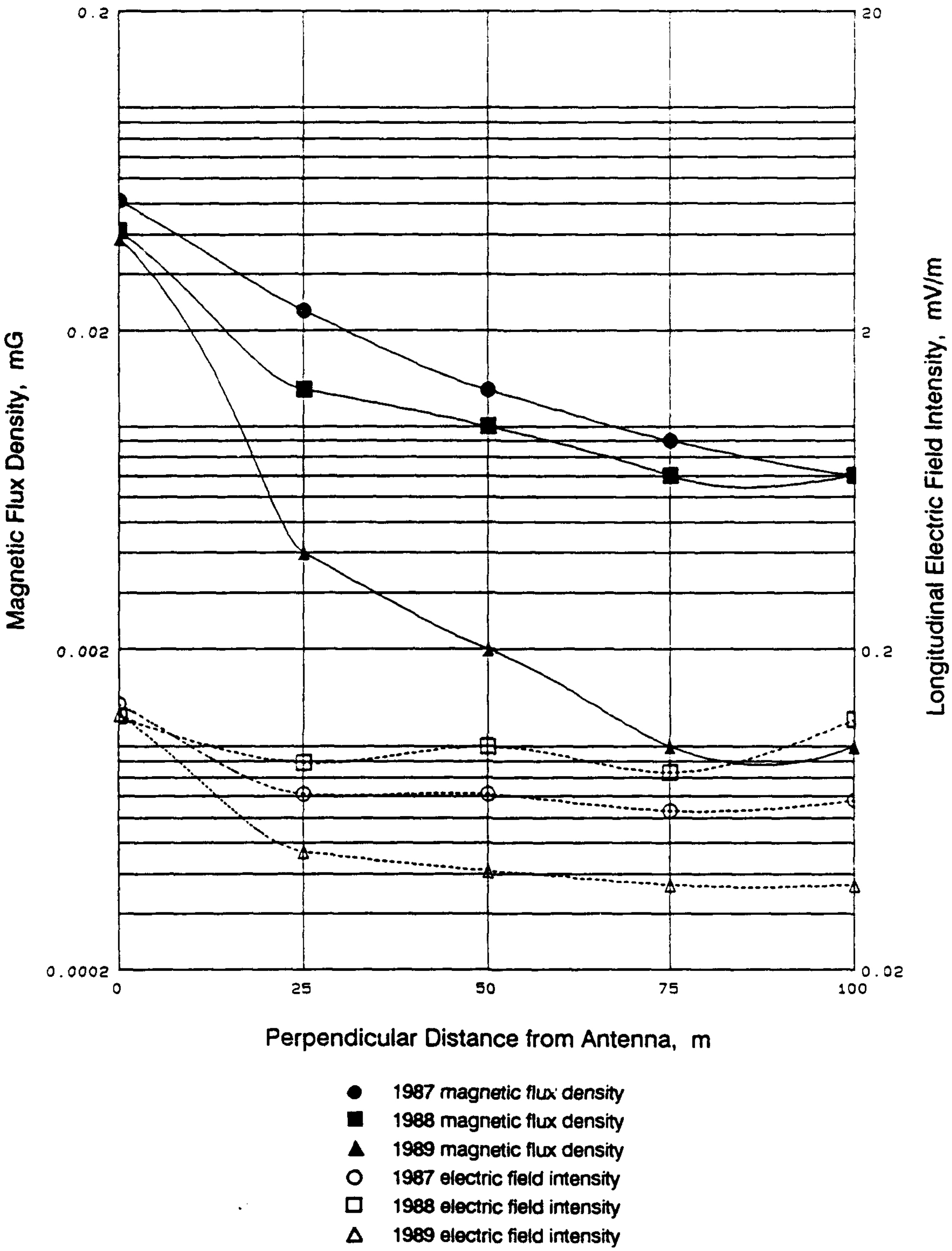


FIGURE A-20. 60 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD PROFILES, NORTH TURNER ROAD; 1T4-10 THROUGH 14.

60297/790

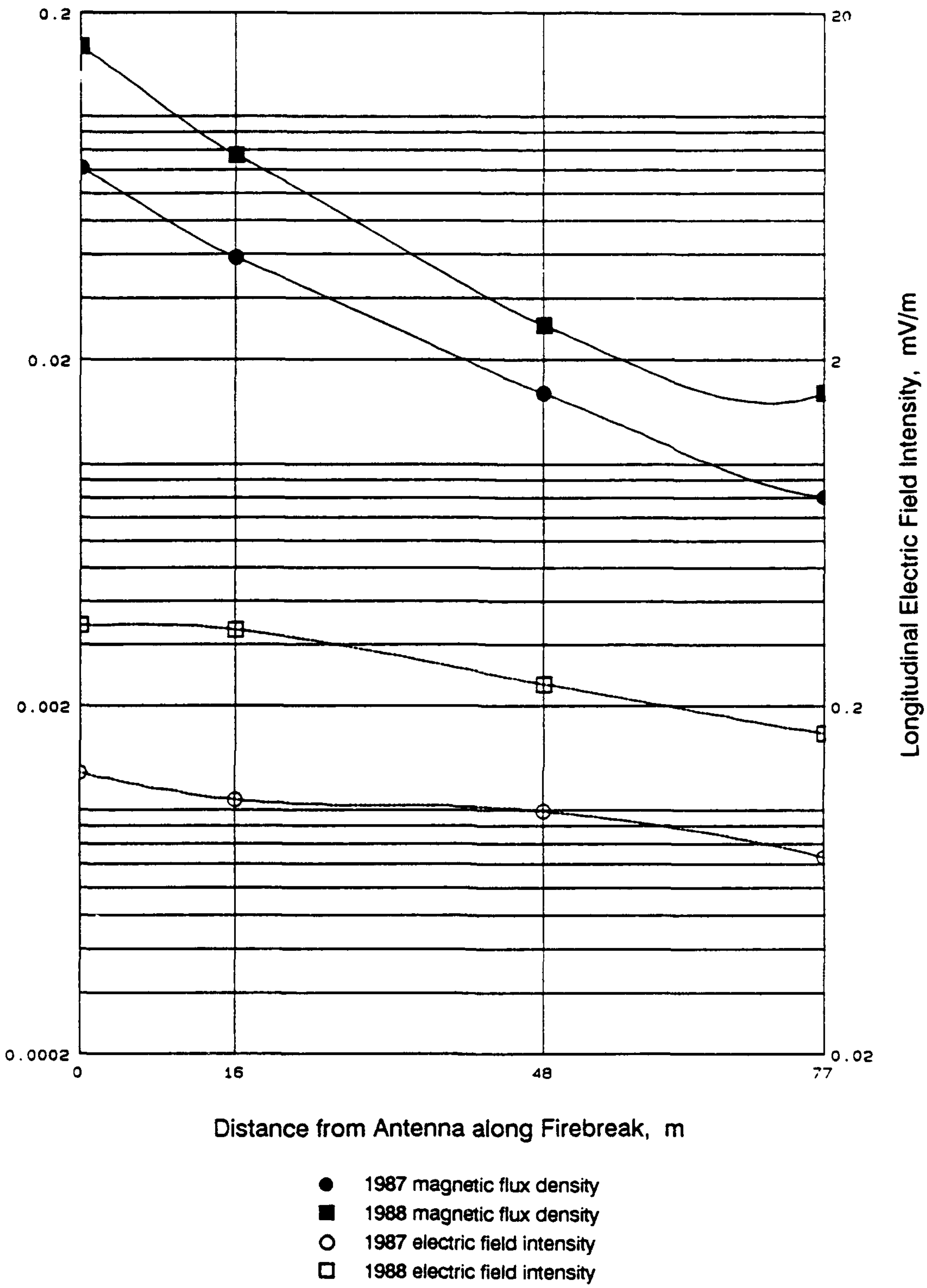


FIGURE A-21. 60 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD PROFILES, FORD RIVER NORTH; 1T5-1, 7, 8, 4.

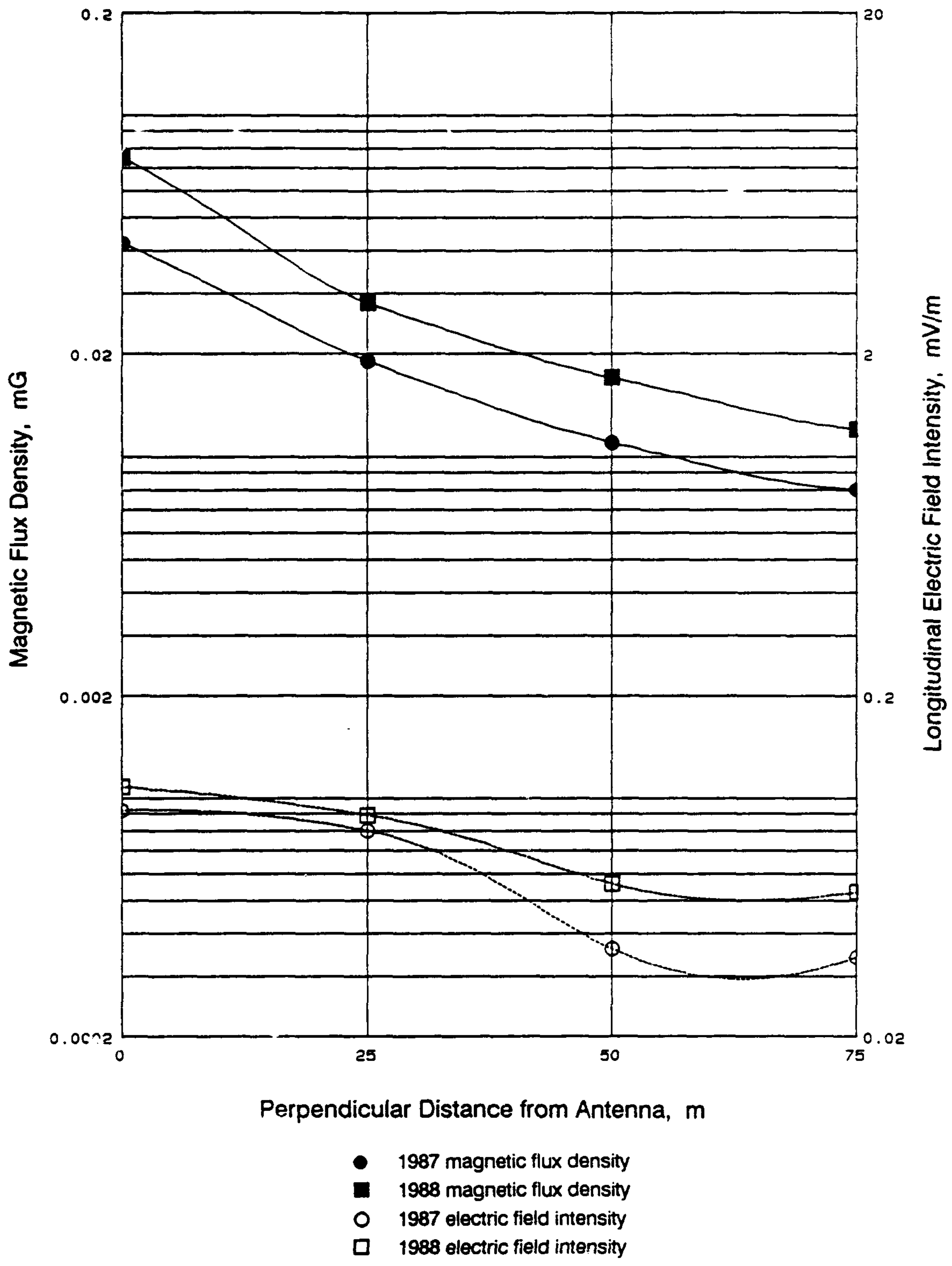


FIGURE A-22. 60 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD PROFILES, FORD RIVER NORTH; 1T5-2, 9, 10, 6.

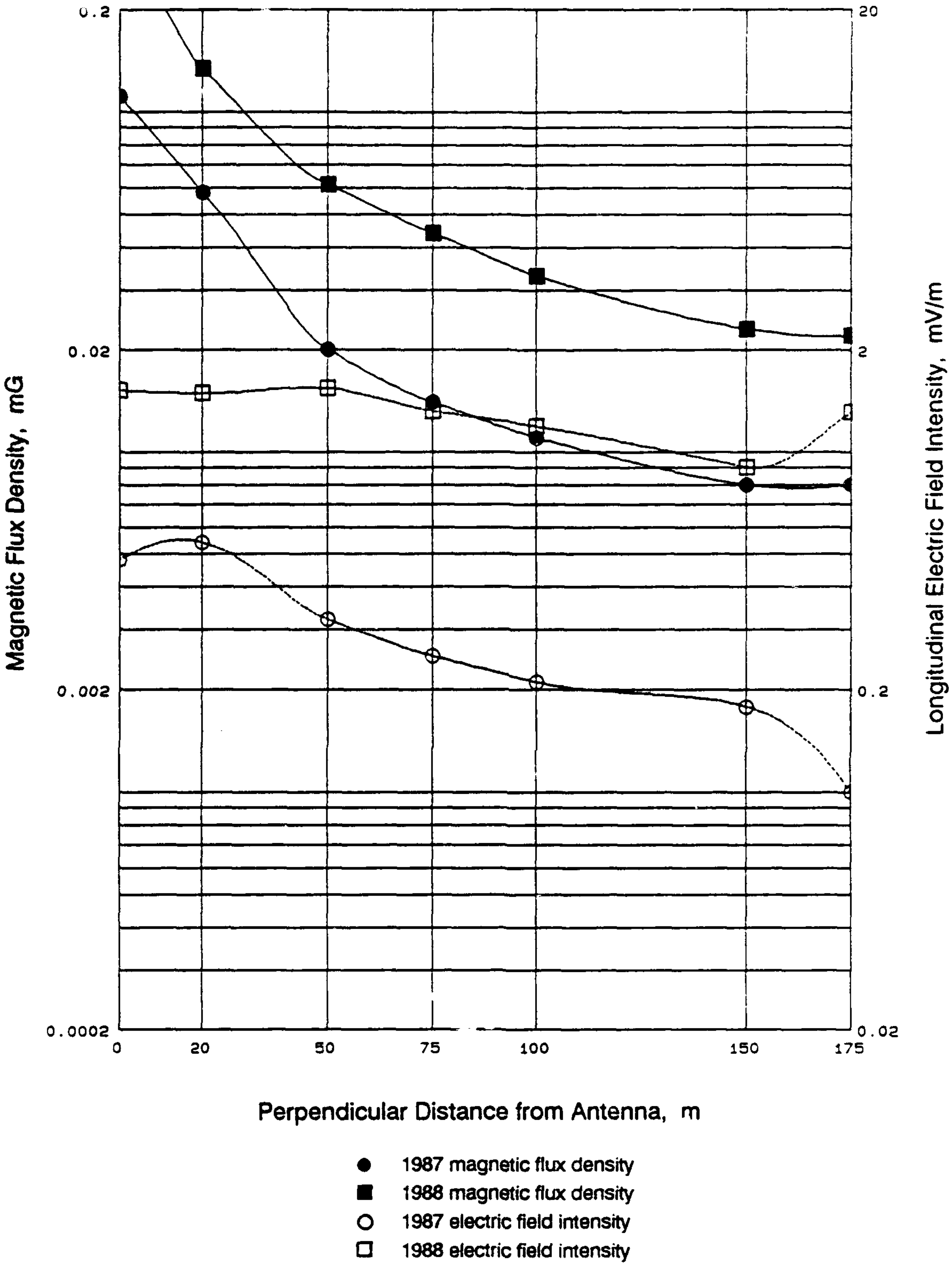


FIGURE A-23. 60 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD PROFILES, FORD RIVER SOUTH; 1T6-2, 1, 3, 4, 5, 6, 7.

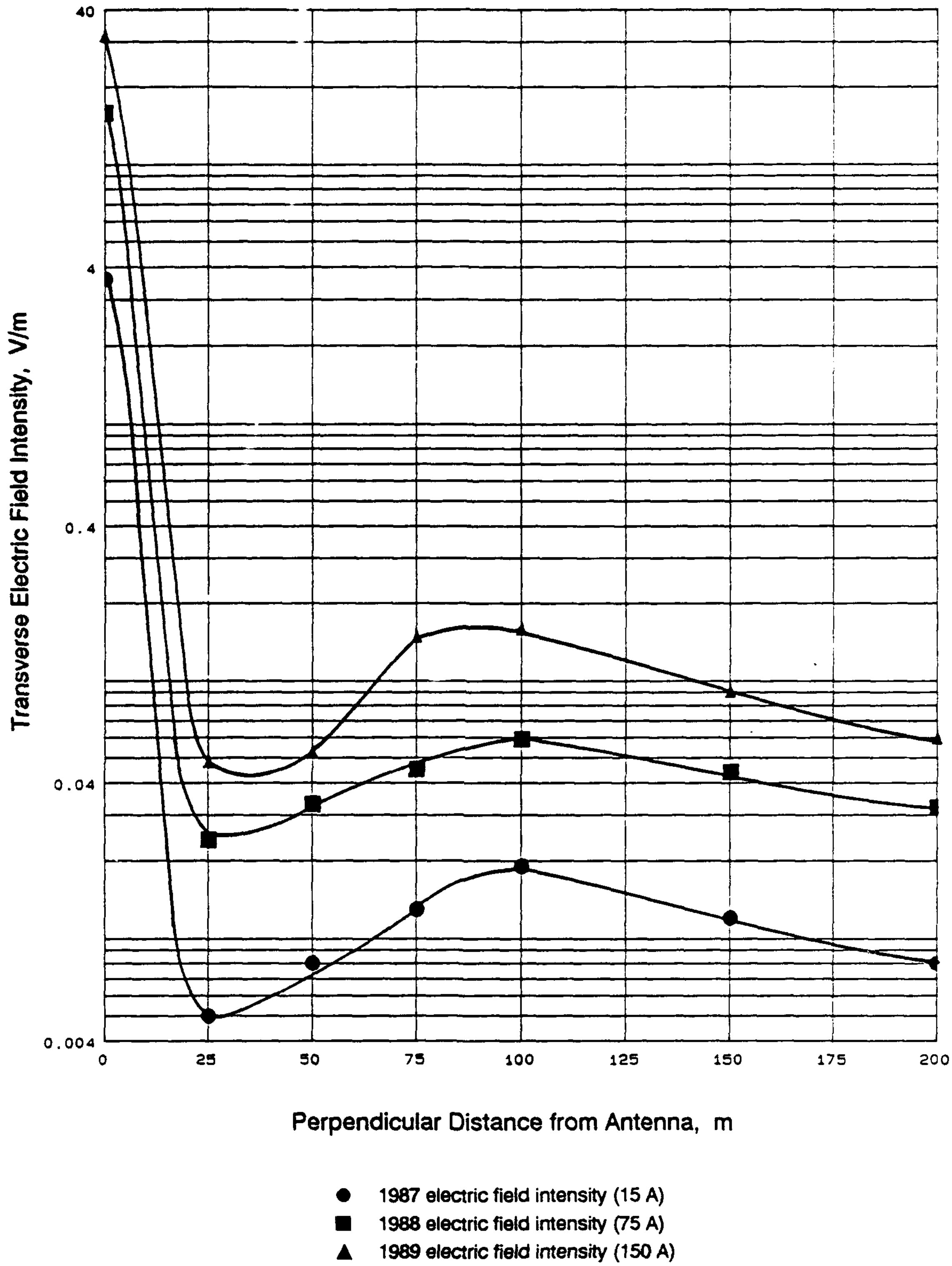
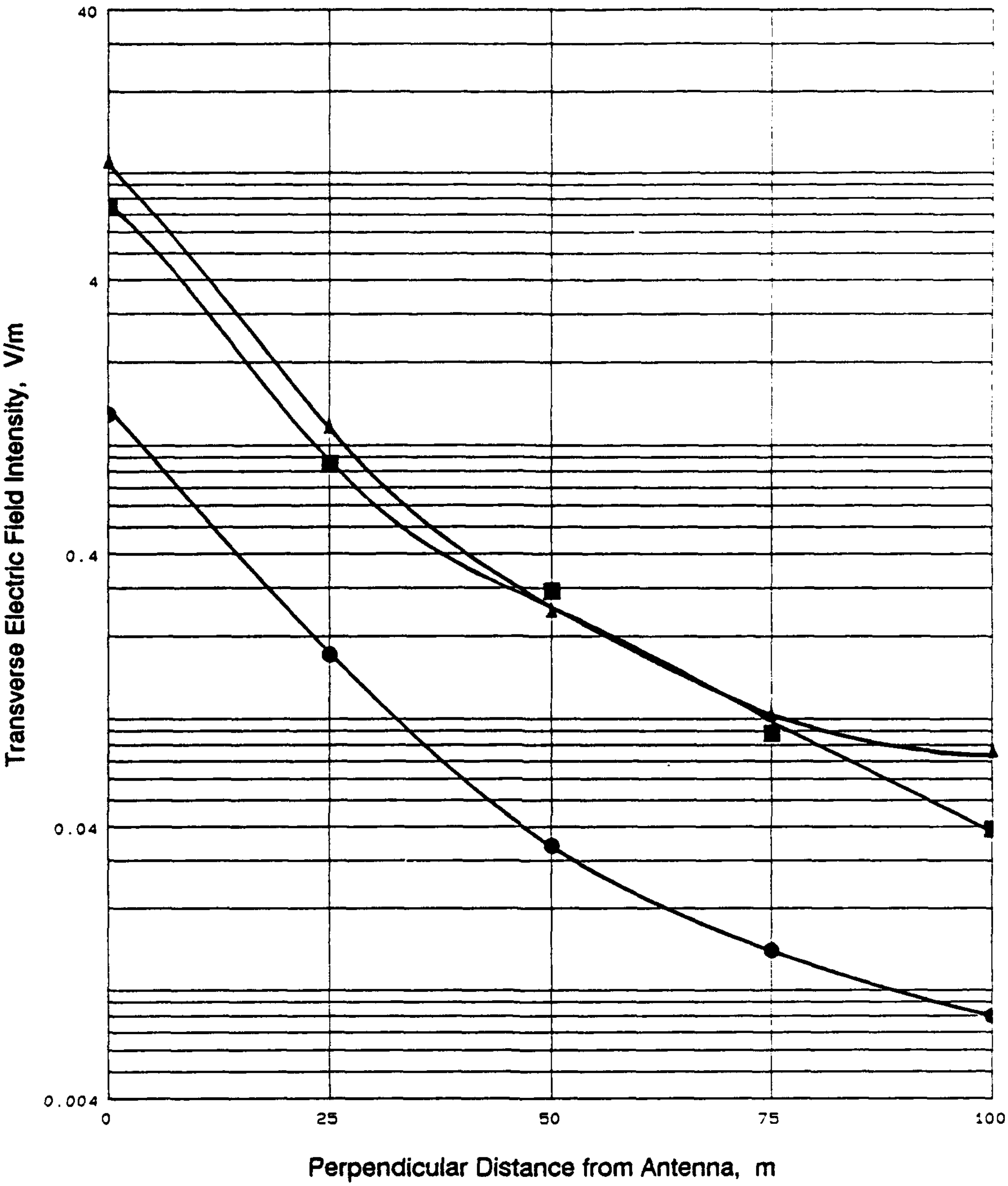


FIGURE A-24. 76 Hz TRANSVERSE ELECTRIC FIELD PROFILES, PIRLOT ROAD; 1T1-21 THROUGH 27.



● 1987 electric field intensity (15 A)
■ 1988 electric field intensity (75 A)
▲ 1989 electric field intensity (150 A)

FIGURE A-25. 76 Hz TRANSVERSE ELECTRIC FIELD PROFILES, CLEVELAND HOMESTEAD; 1T2-5 THROUGH 9.

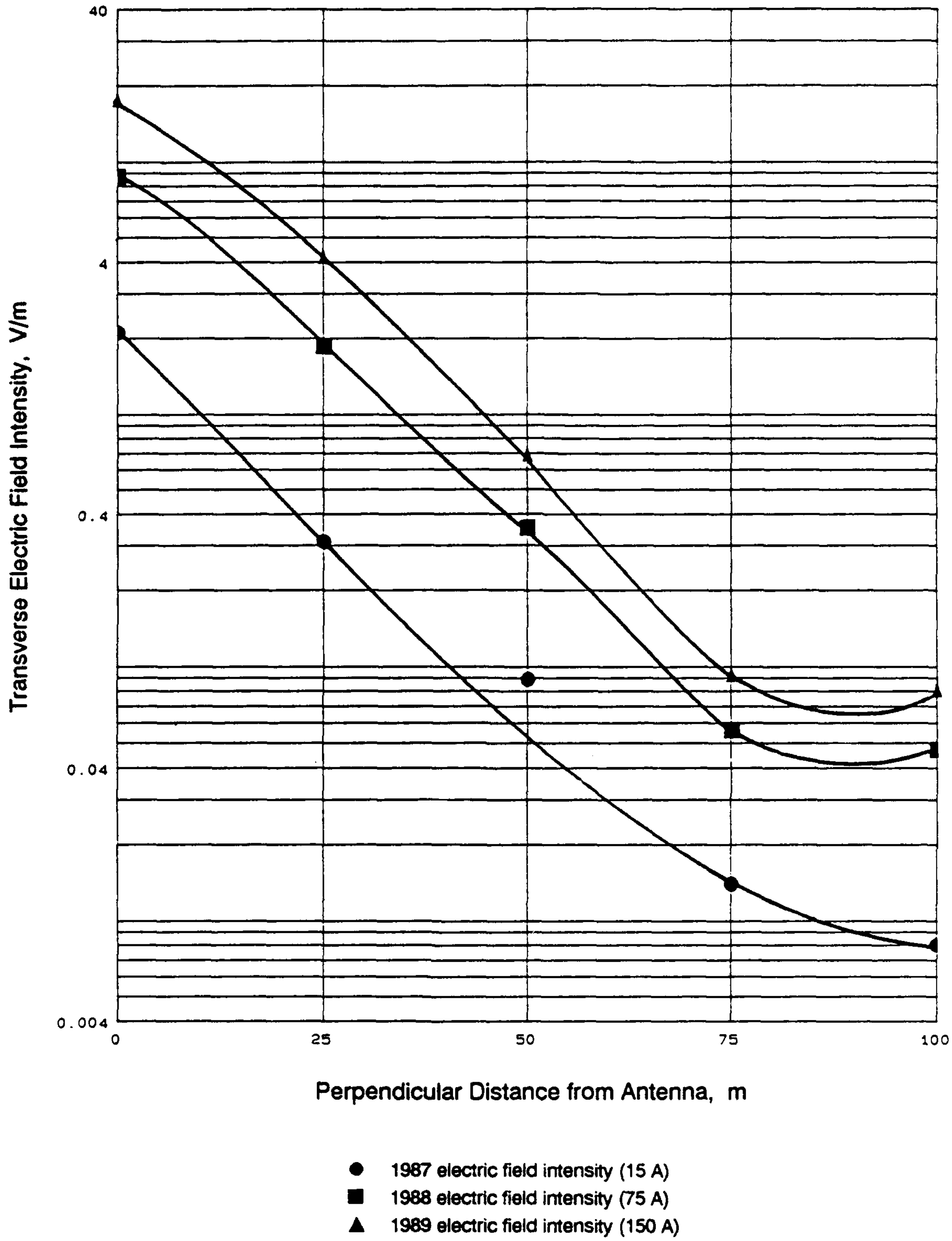


FIGURE A-26. 76 Hz TRANSVERSE ELECTRIC FIELD PROFILES, NORTH TURNER ROAD; 1T4-5 THROUGH 9.

60297/790

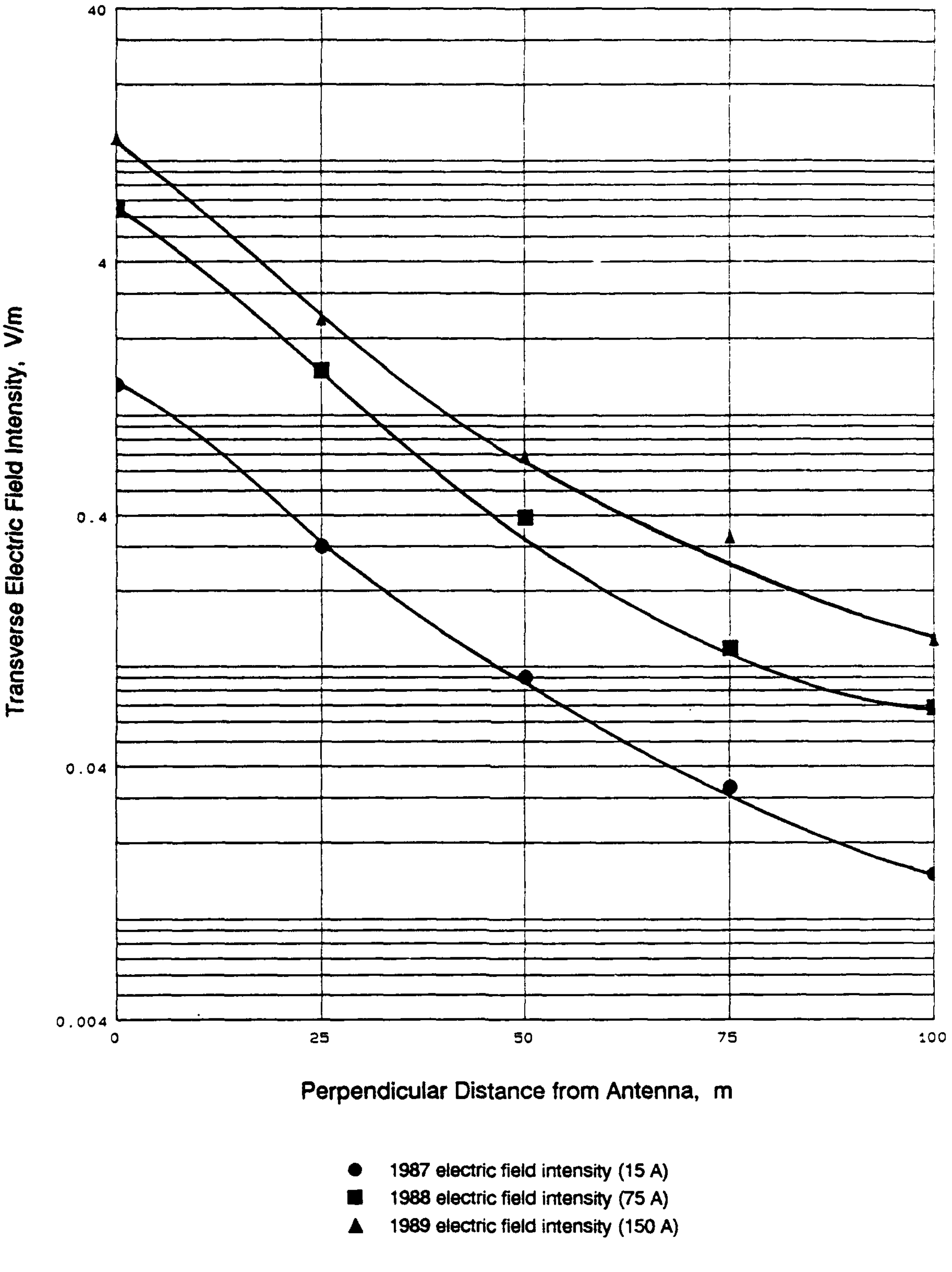


FIGURE A-27. 76 Hz TRANSVERSE ELECTRIC FIELD PROFILES, NORTH TURNER ROAD; 1T4-10 THROUGH 14.

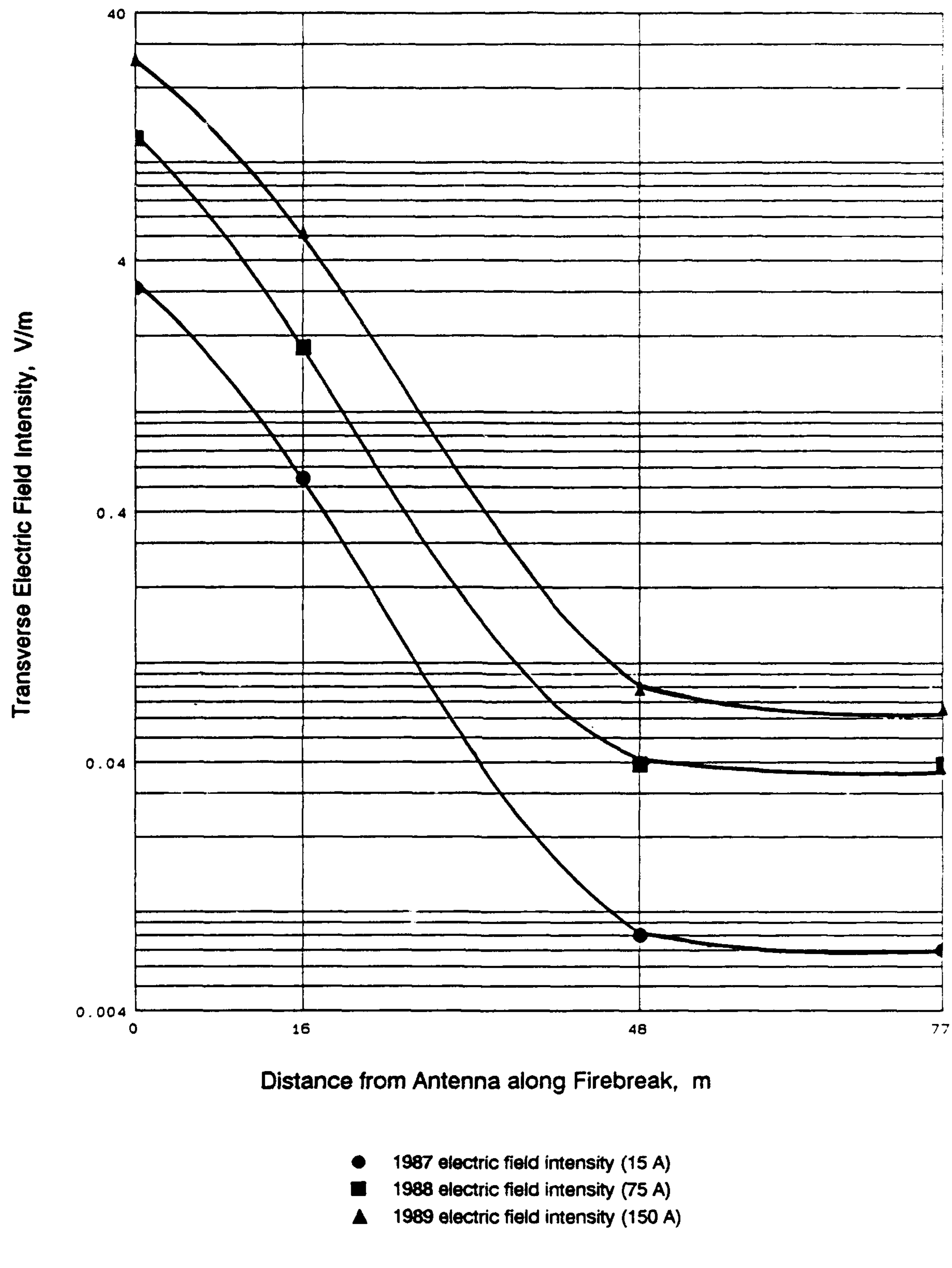


FIGURE A-28. 76 Hz TRANSVERSE ELECTRIC FIELD PROFILES, FORD RIVER NORTH; 1T5-1, 7, 8, 4.

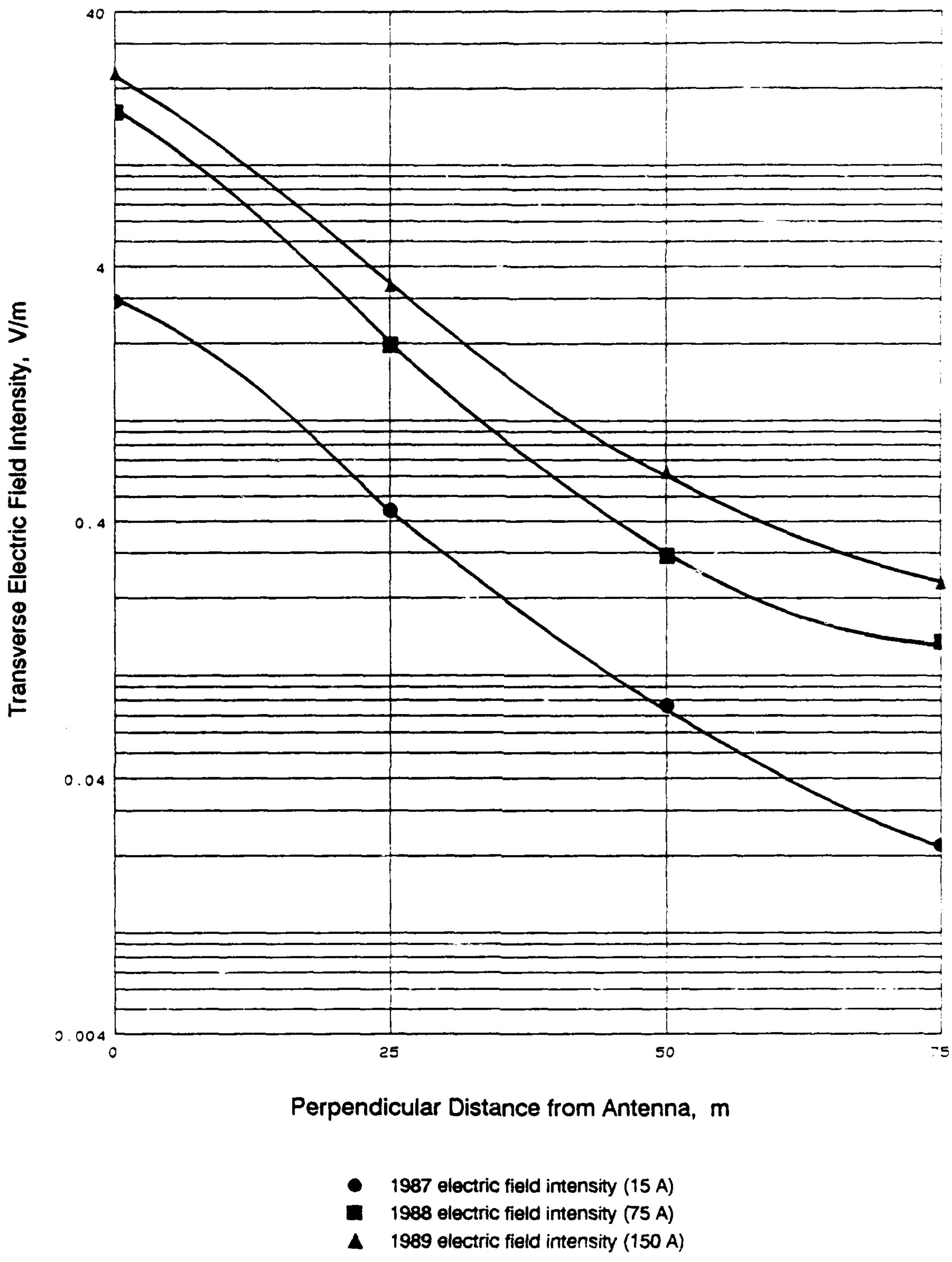


FIGURE A-29. 76 Hz TRANSVERSE ELECTRIC FIELD PROFILES, FORD RIVER NORTH; 1T5-2, 9, 10, 6.

60297/790

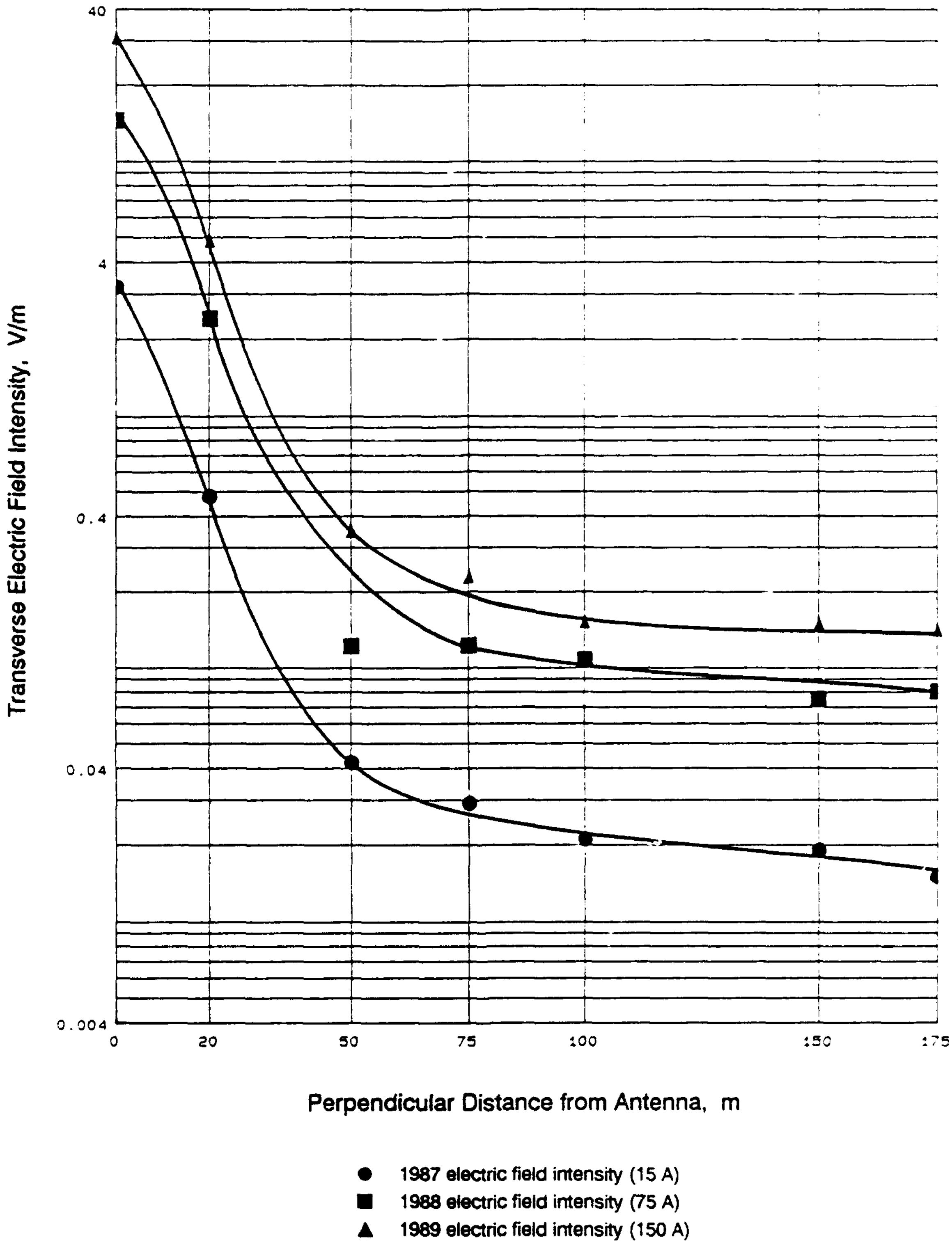


FIGURE A-30. 76 Hz TRANSVERSE ELECTRIC FIELD PROFILES, FORD RIVER SOUTH; 1T6-2, 1, 3, 4, 5, 6, 7.

60297/790

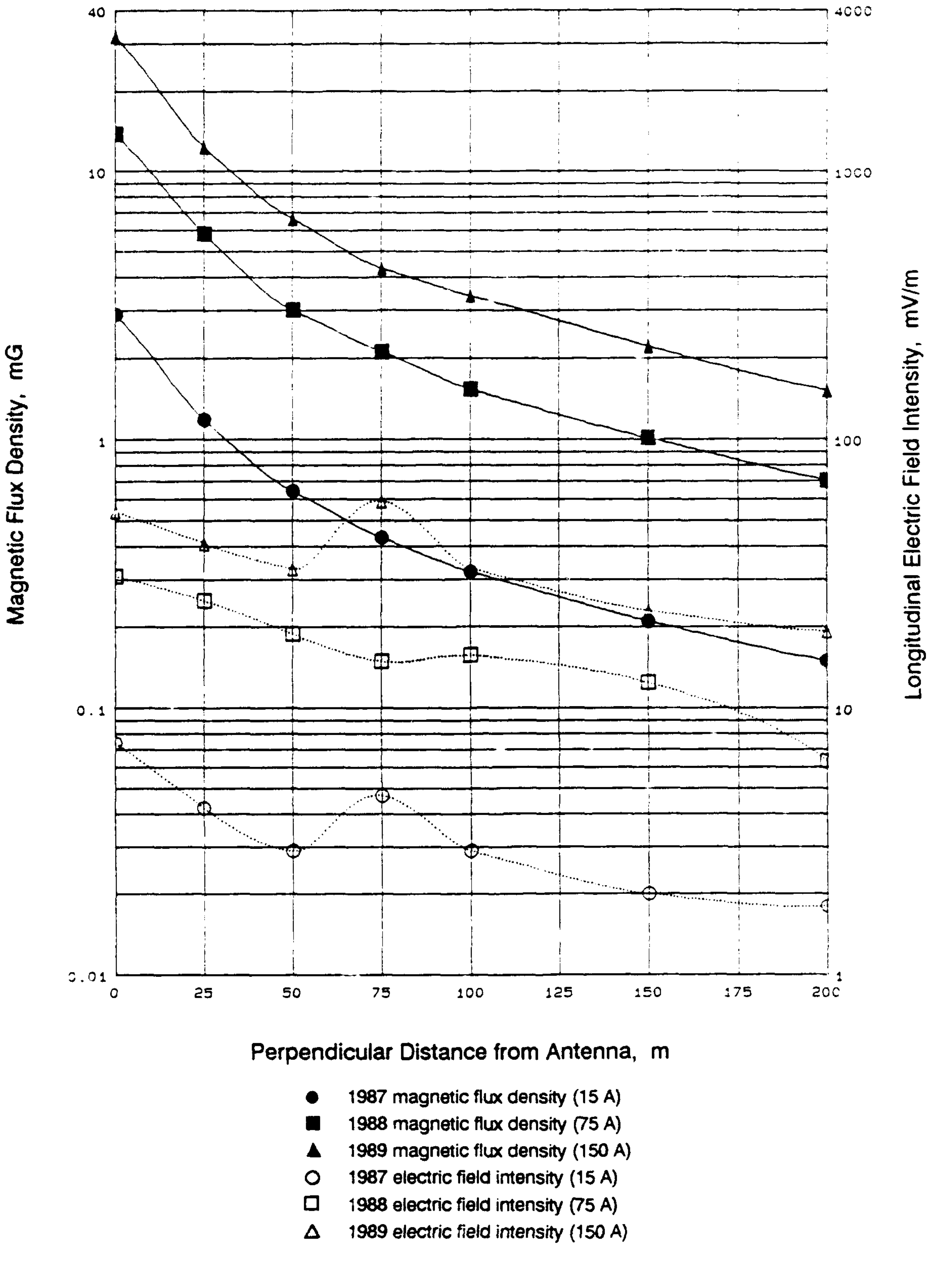


FIGURE A-31. 76 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD PROFILES, PIRLOT ROAD; 1T1-21 THROUGH 27.

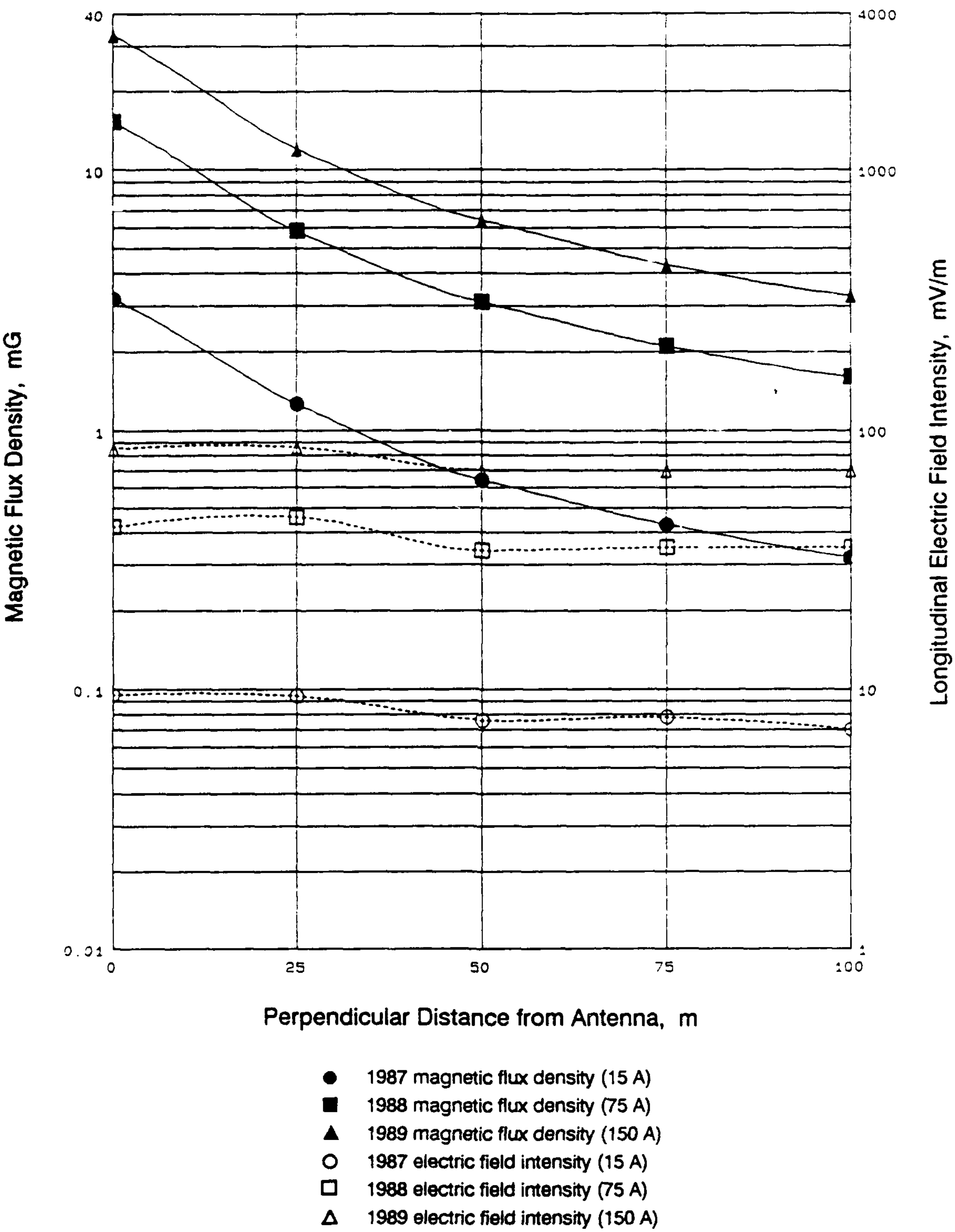


FIGURE A-32. 76 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD PROFILES, CLEVELAND HOMESTEAD; 1T2-5 THROUGH 9.

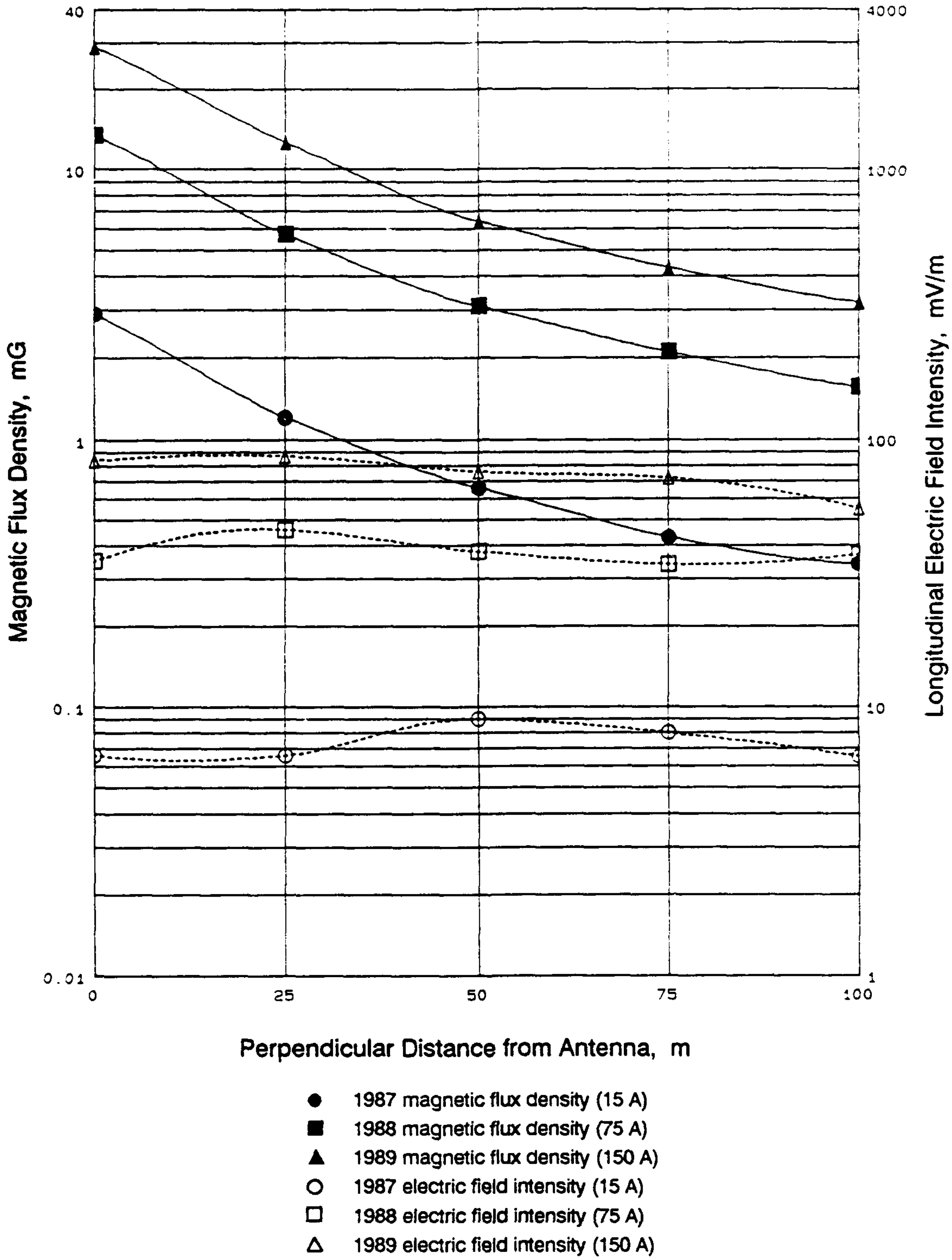
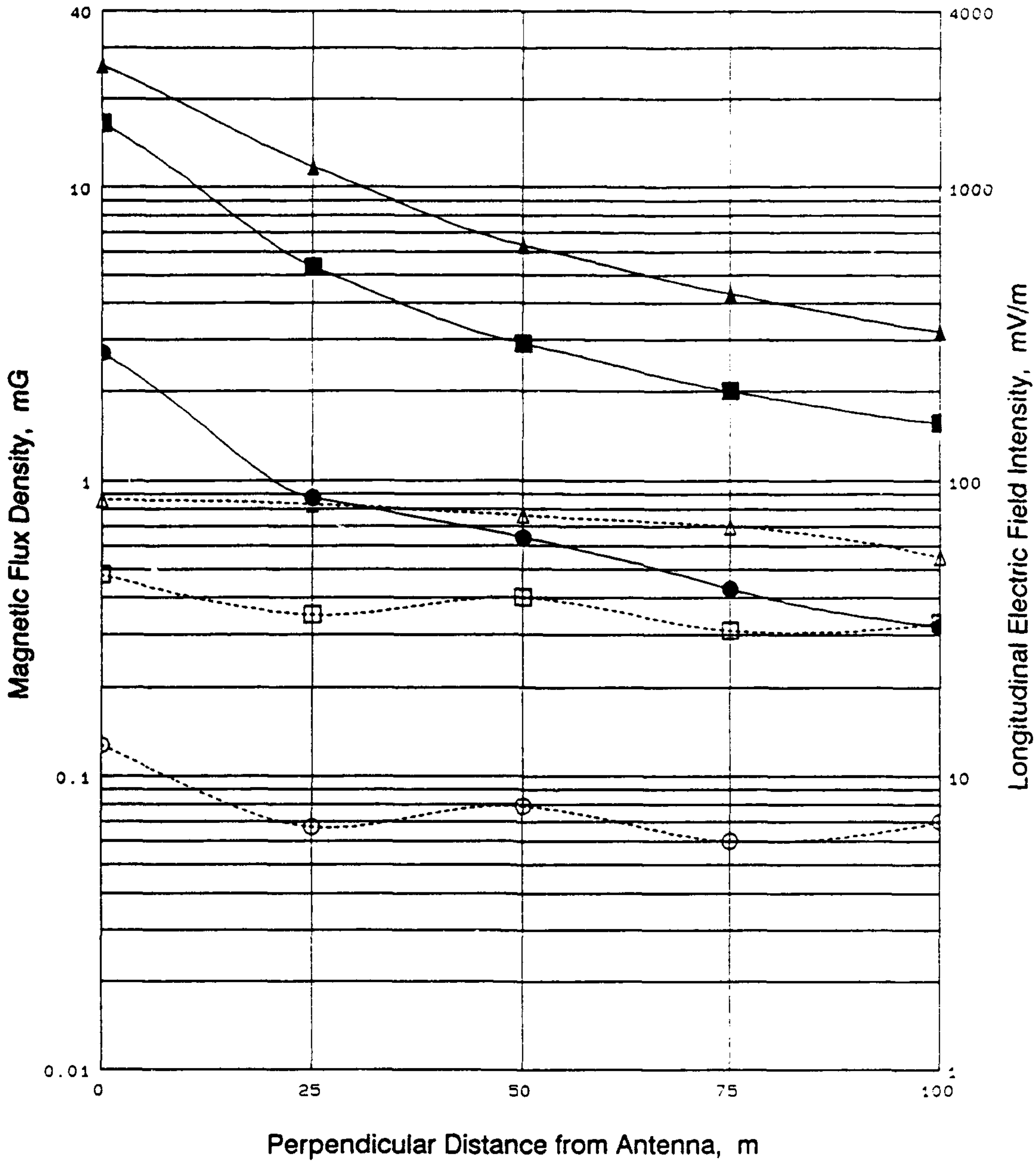


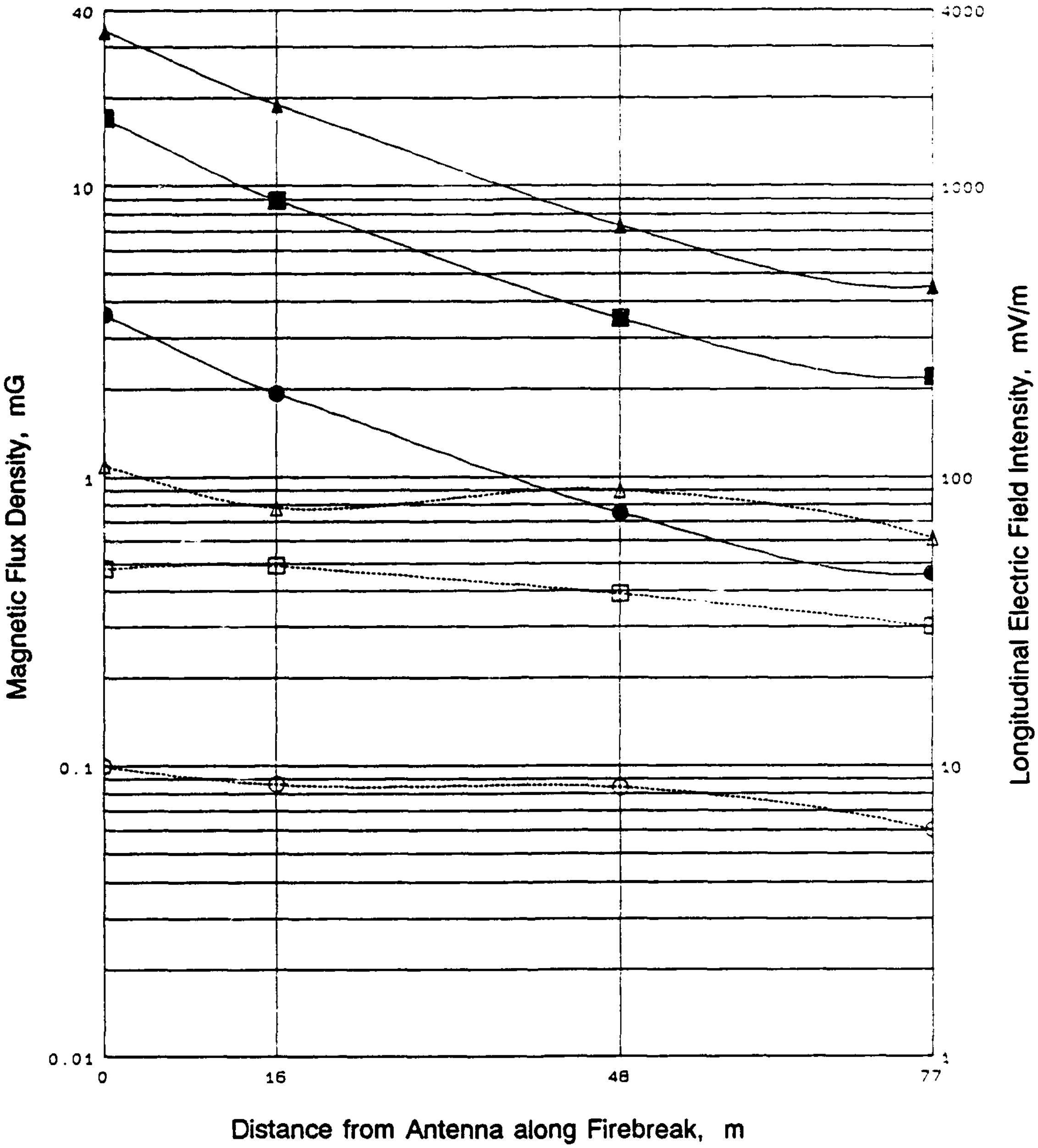
FIGURE A-33. 76 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD PROFILES, NORTH TURNER ROAD; 1T4-5 THROUGH 9.

60297/790



● 1987 magnetic flux density (15 A)
■ 1988 magnetic flux density (75 A)
▲ 1989 magnetic flux density (150 A)
○ 1987 electric field intensity (15 A)
□ 1988 electric field intensity (75 A)
△ 1989 electric field intensity (150 A)

FIGURE A-34. 76 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD PROFILES, NORTH TURNER ROAD; 1T4-10 THROUGH 14.



- ● 1987 magnetic flux density (15 A)
- ■ 1988 magnetic flux density (75 A)
- ▲ 1989 magnetic flux density (150 A)
- ○ 1987 electric field intensity (15 A)
- □ 1988 electric field intensity (75 A)
- △ 1989 electric field intensity (150 A)

FIGURE A-35. 76 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD PROFILES, FORD RIVER NORTH; 1T5-1, 7, 8, 4.

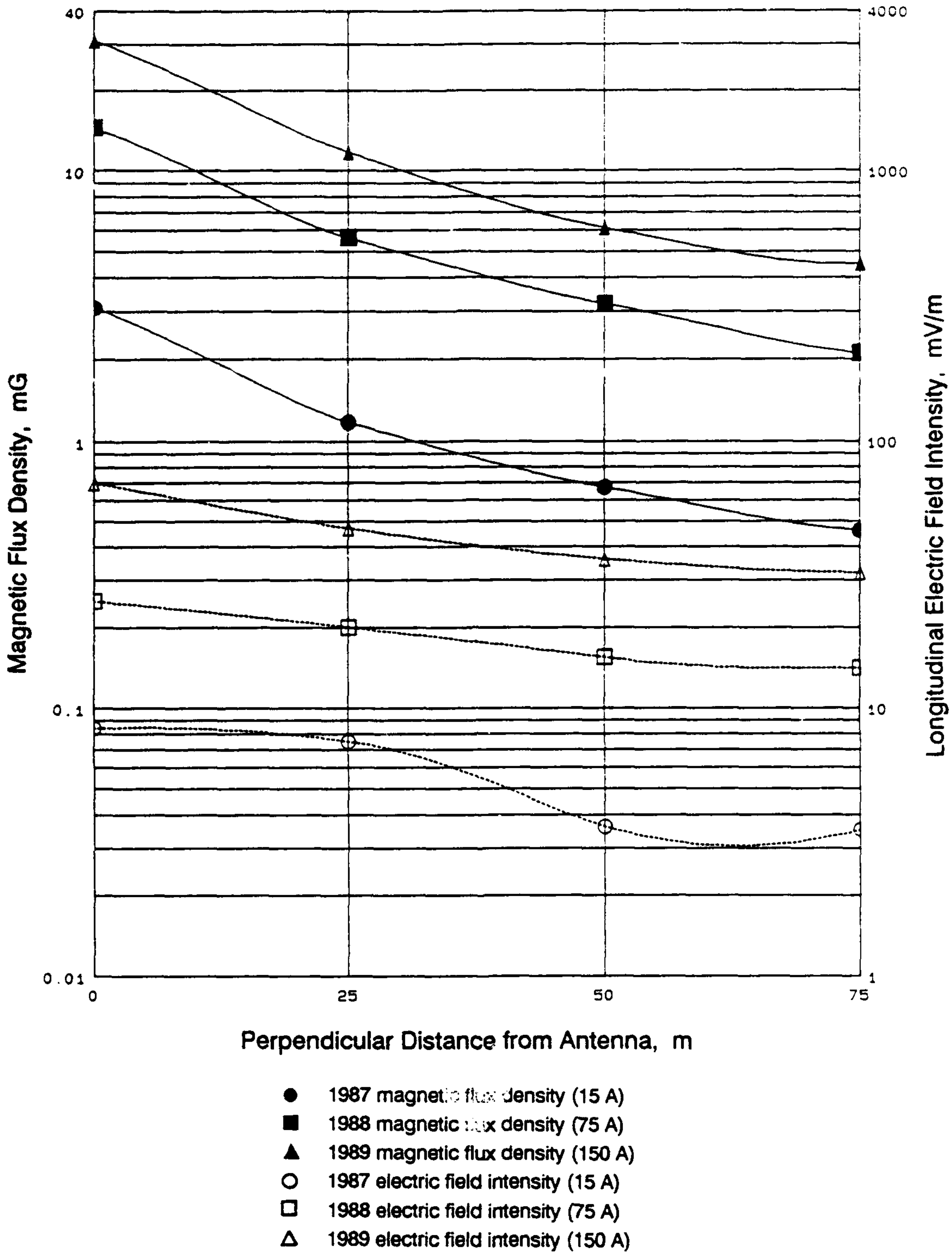


FIGURE A-36. 76 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD PROFILES, FORD RIVER NORTH; 1T5-2, 9, 10, 6.

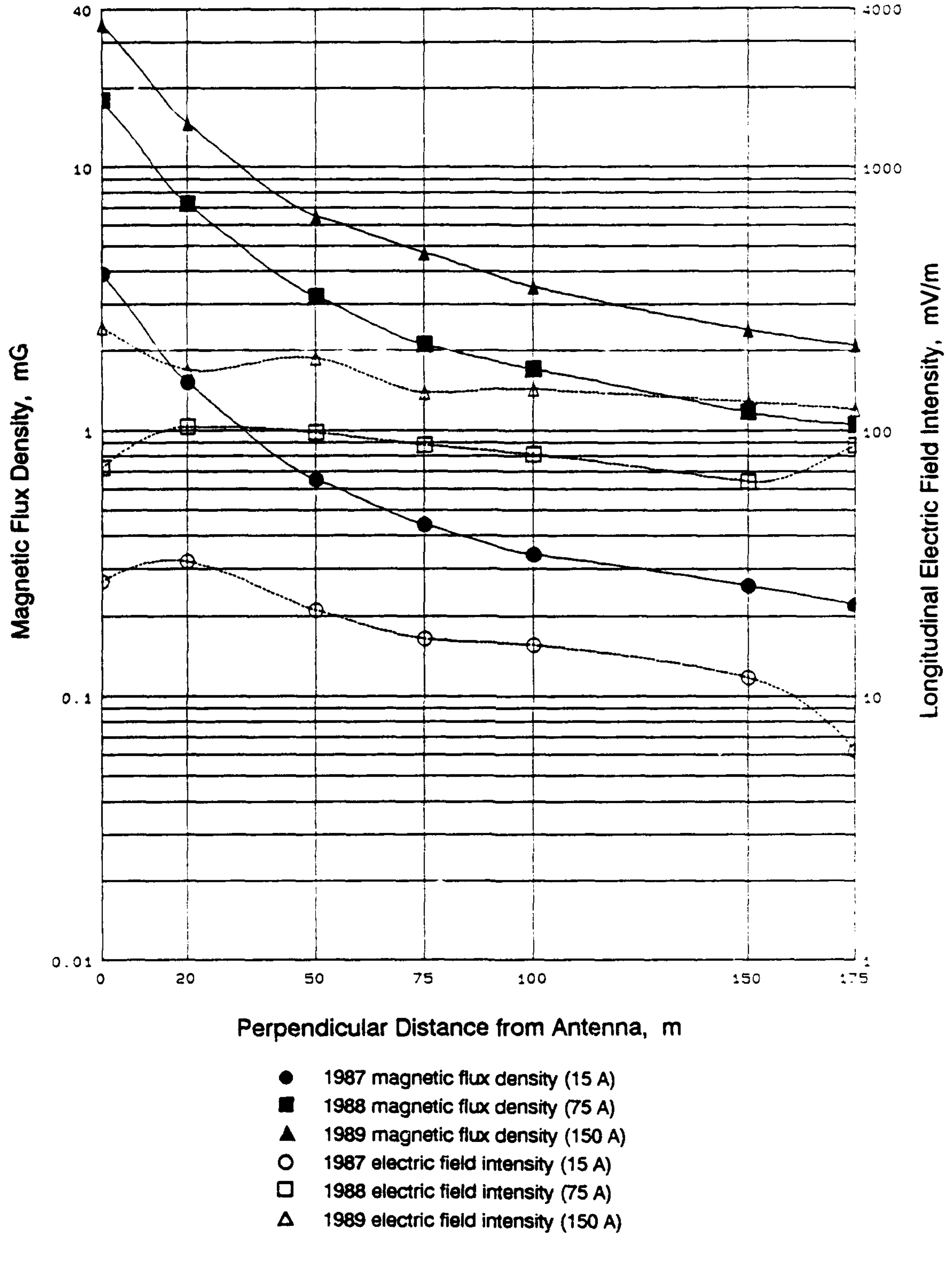


FIGURE A-37. 76 Hz MAGNETIC AND LONGITUDINAL ELECTRIC FIELD PROFILES, FORD RIVER SOUTH; 1T6-2, 1, 3, 4, 5, 6, 7.

60297/790

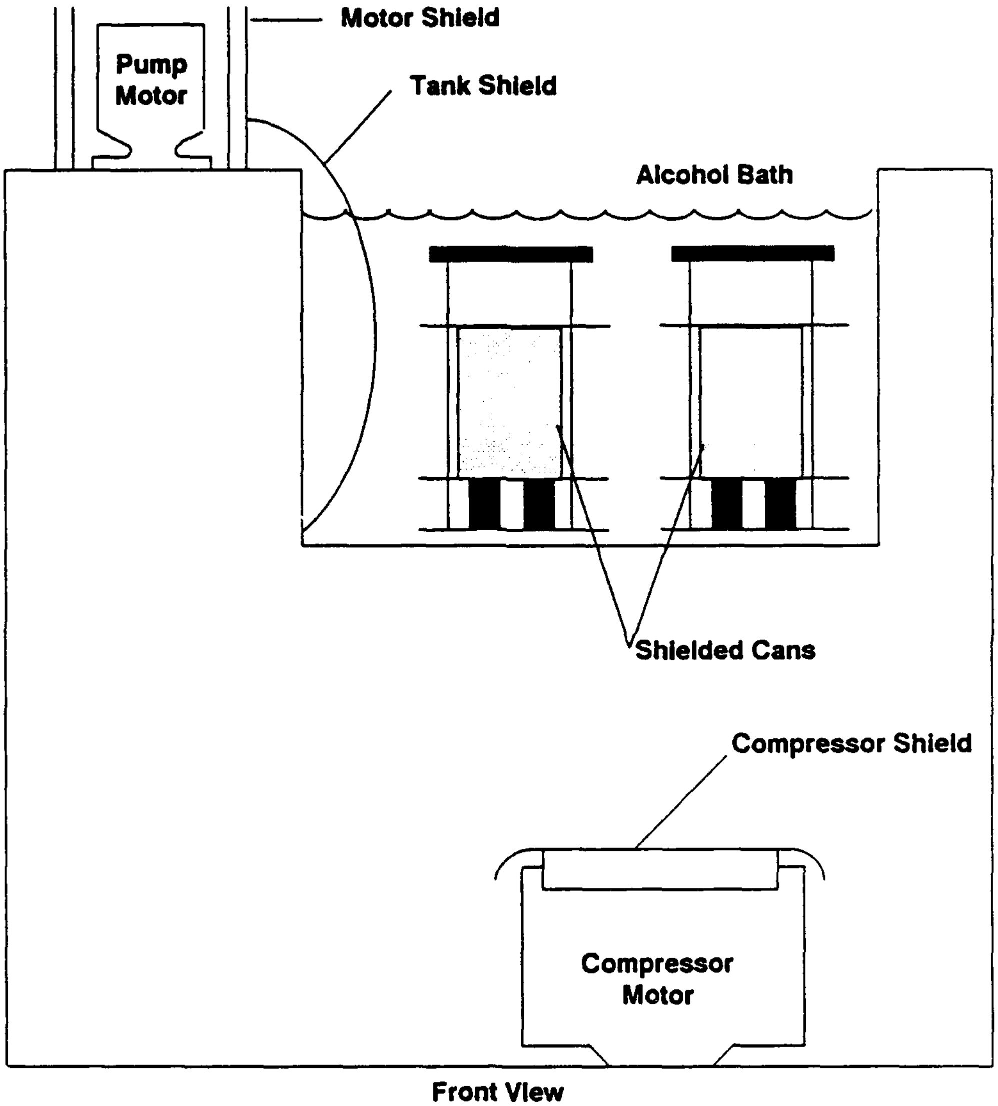


FIGURE A-38. MAGNETIC SHIELD LOCATIONS AT BATH.

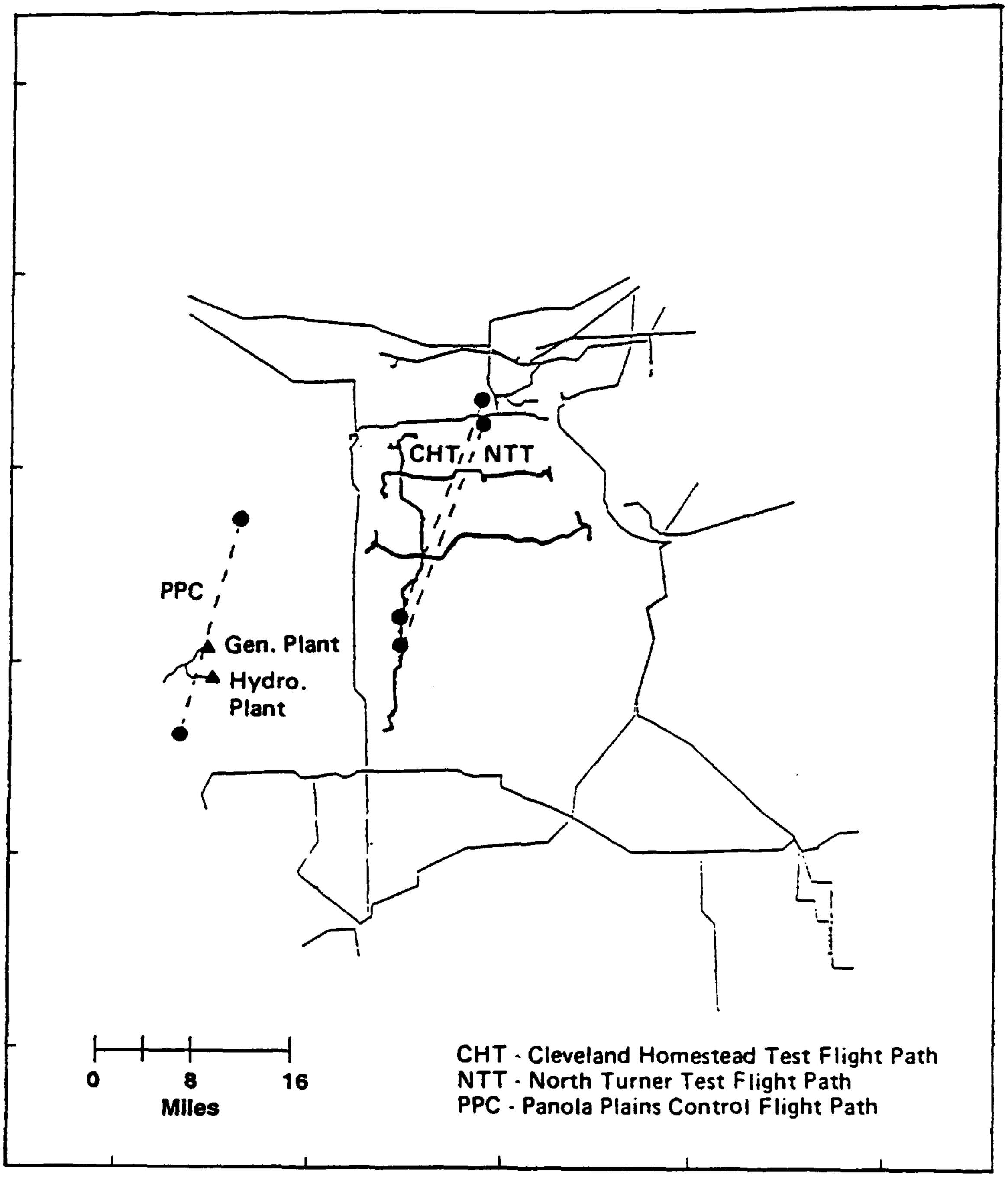


FIGURE A-39. BIRD DISPLACEMENT FLIGHT PATH LOCATIONS RELATIVE TO HIGH VOLTAGE 60 Hz TRANSMISSION LINES.

60297/190

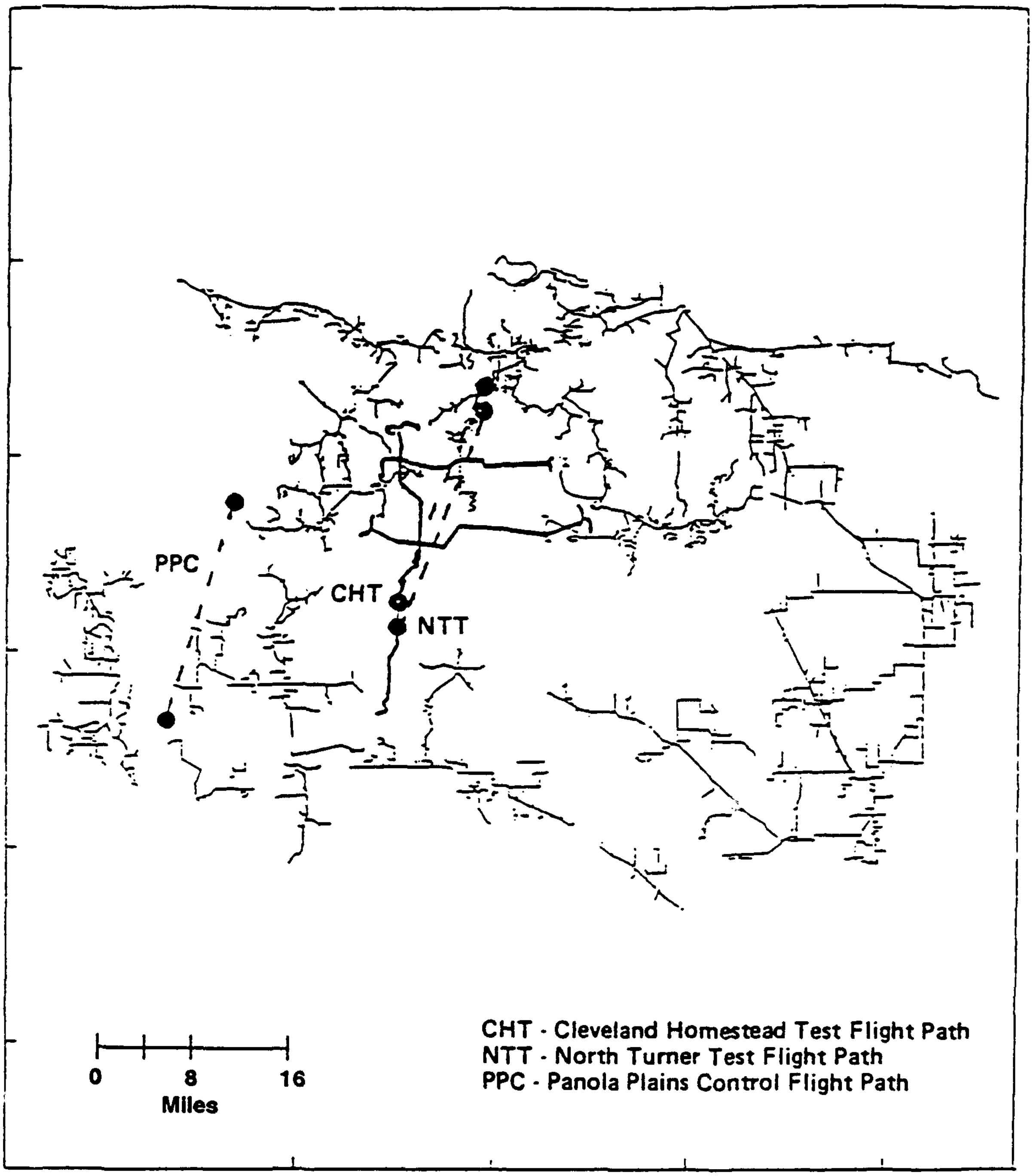


FIGURE A-40. BIRD DISPLACEMENT FLIGHT PATH LOCATIONS RELATIVE TO 60 Hz POWER DISTRIBUTION LINES.

TABLE A-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
(page 1 of 4)

Site No., Meas. Pt.	1983 a	1984 a	1985 a	1986 b	1987 c	1988 c	1989 d
1C1-2	<	<	<	--	--	--	--
1C1-3	-	-	<	<	<	<	<
1C1-4	-	-	-	<	<	<	<
1C3-1	<	<	<	<	<	<	<
1C3-2	<	<	--	--	--	--	--
1C3-3	-	-	-	<	<	<	<
1C4-1	-	0.001	<	<	<	<	<
1C4-2	-	<0.001	<	--	--	--	--
1C4-3	-	<0.001	<	<	--	--	--
1C4-4	-	-	<	<	<	<	<
1C4-5	-	-	-	-	<	<	<
1D3-1	-	-	-	<	<	<	<
1C6-1	-	0.001	<	<	<	<	<
1C6-3	-	-	<	<	<	<	<
1C6-4	-	-	<	<	<	<	<
1L1-4	-	-	-	0.042	0.047	0.062	/
1L4-1	-	-	-	-	-	<	<

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
\# = measurement not possible.
< = est. <0.001 V/m based on E-field in ground.

TABLE A-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
(page 2 of 4)

Site No., Meas. Pt.	1983 [a]	1984 [a]	1985 [a]	1986 [b]	1987 [c]	1988 [c]	1989 [d]
1T1-1	0.001	<	<	--	--	--	--
1T1-3	-	<	<	--	--	--	--
1T1-4	-	<	<	--	--	--	--
1T1-10	-	<	<	--	--	--	--
1T1-12	-	-	<	--	--	--	--
1T1-13	-	-	<	--	--	--	--
1T1-14	-	-	-	<	<	<	<
1T1-15	-	-	-	<	<	<	#
1T1-16	-	-	-	<	<	<	#
1T1-17	-	-	-	<	<	<	#
1T1-18	-	-	-	<	<	<	#
1T1-19	-	-	-	<	<	<	#
1T1-20	-	-	-	<	<	<	#
1T1-28	-	-	-	-	-	<	#
1T1-29	-	-	-	-	-	<	#
1T1-30	-	-	-	-	-	<	#
1T1-31	-	-	-	-	-	<	#
1T1-21	-	-	-	<	0.086	0.49	0.109
1T1-22	-	-	-	<	<0.001	<	<0.001
1T1-23	-	-	-	<	<	<	<0.001
1T1-24	-	-	-	<	<	<	<
1T1-25	-	-	-	<	<	<	<
1T1-26	-	-	-	<	<	<	<
1T1-27	-	-	-	<	<	<	<

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
= measurement not possible.
< = est. <0.001 V/m based on E-field in ground.

TABLE A-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
(page 3 of 4)

Site No., Meas. Pt.	1983 a	1984 a	1985 a	1986 b	1987 c	1988 c	1989 d
1T2-1	<0.001	0.001	<	<	--	--	--
1T2-2	-	-	-	<	--	--	--
1T2-3	-	-	-	<	--	--	--
1T2-4	-	-	-	<	--	--	--
1T2-5	-	-	-	-	0.198	0.053	0.016
1T2-6	-	-	-	-	0.024	0.007	0.002
1T2-7	-	-	-	-	0.005	<	<
1T2-8	-	-	-	-	0.002	<	<
1T2-9	-	-	-	-	<0.001	<	<
1D1-1	-	-	-	2.5	2.0	9.2	0.74
1T4-1	-	<0.001	<	--	--	--	--
1T4-3	-	-	<	--	--	--	--
1T4-4	-	-	<	--	--	--	--
1T4-5	-	-	-	<	0.094	0.066	0.004
1T4-6	-	-	-	<	0.014	0.014	0.003
1T4-7	-	-	-	<	0.004	0.002	<0.001
1T4-8	-	-	-	<	<0.001	<0.001	<
1T4-9	-	-	-	<	<	<	<
1T4-10	-	-	-	-	0.062	0.041	0.009
1T4-11	-	-	-	-	0.014	0.006	0.002
1T4-12	-	-	-	-	0.004	0.003	<
1T4-13	-	-	-	-	0.002	0.002	<
1T4-14	-	-	-	-	0.001	0.001	<

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
\# = measurement not possible.
< = est. <0.001 V/m based on E-field in ground.

TABLE A-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
(page 4 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]
1D2-1	-	-	-	<	<	<	0.004
1T5-1	-	<0.001	<	<	0.118	0.157	#
1T5-7	-	-	-	-	0.019	0.019	#
1T5-8	-	-	-	-	<0.001	<	#
1T5-4	-	-	-	<	<	<	#
1T5-2	<0.001	<0.001	<	<	0.074	0.130	#
1T5-9	-	-	-	-	0.014	0.017	#
1T5-10	-	-	-	-	0.002	0.004	#
1T5-6	-	-	-	<	<0.001	<	#
1T5-3	-	-	-	<	--	--	--
1T5-5	-	-	-	<	<0.001	0.001	#
1T6-2	-	-	-	-	0.162	0.46	#
1T6-1	<0.001	<0.001,0.001	<	<	0.024	0.079	#
1T6-3	-	-	-	-	0.003	0.003	#
1T6-4	-	-	-	-	0.001	0.003	#
1T6-5	-	-	-	-	0.001	0.002	#
1T6-6	-	-	-	-	0.001	<0.001	#
1T6-7	-	-	-	-	<0.001	<0.001	#

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
= measurement not possible.
< = est. <0.001 V/m based on E-field in ground.

TABLE A-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITES (mV/m)
Small Mammals and Nesting Birds Studies
(page 1 of 4)

Site No., Meas. Pt.	1983 [a]	1984 [a]	1985 [a]	1986 [b]	1987 [c]	1988 [c]	1989 [d]
1C1-2	0.041	0.146	0.056	--	--	--	--
1C1-3	-	-	0.128	0.082	0.114	0.59	0.053
1C1-4	-	-	-	0.117	0.114	0.085	0.22
1C3-1	0.106	0.26	0.133	0.080	0.118	0.085	0.135
1C3-2	0.125	0.191	/	--	--	--	--
1C3-3	-	-	-	0.074	0.178	0.148	0.22
1C4-1	-	0.028,0.030	0.045	0.065	0.093	0.087	0.041
1C4-2	-	0.019,0.023	0.015	--	--	--	--
1C4-3	-	0.036,0.065	0.103	0.118	--	--	--
1C4-4	-	-	0.009,0.017	0.011	0.011	0.011	0.010
1C4-5	-	-	-	-	0.037	0.046	0.021
1D3-1	-	-	-	0.052	0.156	0.053	0.29
1C6-1	-	0.072	0.095	0.088	0.106	0.057	0.102
1C6-3	-	-	0.123	0.109	0.141	0.053	0.122
1C6-4	-	-	0.038	0.007	0.020	0.013	0.013
1L1-4	-	-	-	3.9	8.9	5.9	#
1L4-1	-	-	-	-	-	0.019	0.013

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
\# = measurement not possible.

TABLE A-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITES (mV/m)
Small Mammals and Nesting Birds Studies
(page 2 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]
1T1-1	0.090	0.091	0.131	--	--	--	--
1T1-3	-	0.21	0.179	--	--	--	--
1T1-4	-	0.174	0.171	--	--	--	--
1T1-10	-	0.097	0.147	--	--	--	--
1T1-12	-	-	0.033	--	--	--	--
1T1-13	-	-	0.034	--	--	--	--
1T1-14	-	-	-	0.102	0.058	0.29	0.071
1T1-15	-	-	-	0.040	0.029	0.064	#
1T1-16	-	-	-	0.115	0.102	0.40	#
1T1-17	-	-	-	0.118	0.128	0.37	#
1T1-18	-	-	-	0.100	0.104	0.46	#
1T1-19	-	-	-	0.112	0.132	0.43	#
1T1-20	-	-	-	0.118	0.123	0.43	#
1T1-28	-	-	-	-	-	0.018	#
1T1-29	-	-	-	-	-	0.014	#
1T1-30	-	-	-	-	-	0.019	#
1T1-31	-	-	-	-	-	0.022	#
1T1-21	-	-	-	0.082	0.082	0.53	0.113
1T1-22	-	-	-	0.050	0.047	0.40	0.086
1T1-23	-	-	-	0.037	0.037	0.31	0.068
1T1-24	-	-	-	0.042	0.058	0.23	0.126
1T1-25	-	-	-	0.033	0.035	0.26	0.070
1T1-26	-	-	-	0.022	0.025	0.20	0.052
1T1-27	-	-	-	0.014	0.021	0.094	0.056

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
\# = measurement not possible.

TABLE A-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITES (mV/m)
Small Mammals and Nesting Birds Studies
(page 3 of 4)

Site No., Meas. Pt.	1983 [a]	1984 [a]	1985 [a]	1986 [b]	1987 [c]	1988 [c]	1989 [d]
1T2-1	0.170	0.22	0.197	0.122	--	--	--
1T2-2	-	-	-	0.047	--	--	--
1T2-3	-	-	-	0.083	--	--	--
1T2-4	-	-	-	0.044	--	--	--
1T2-5	-	-	-	-	0.074	0.074	0.047
1T2-6	-	-	-	-	0.069	0.087	0.064
1T2-7	-	-	-	-	0.047	0.062	0.040
1T2-8	-	-	-	-	0.051	0.067	0.055
1T2-9	-	-	-	-	0.055	0.087	0.031
1D1-1	-	-	-	9.6	2.4	1.15	2.7
1T4-1	-	0.178,0.184	0.150	--	--	--	--
1T4-3	-	-	0.22	--	--	--	--
1T4-4	-	-	0.131	--	--	--	--
1T4-5	-	-	-	0.052	0.081	0.135	0.035
1T4-6	-	-	-	0.104	0.066	0.128	0.039
1T4-7	-	-	-	0.102	0.090	0.128	0.036
1T4-8	-	-	-	0.082	0.078	0.096	0.032
1T4-9	-	-	-	0.088	0.063	0.098	0.032
1T4-10	-	-	-	-	0.135	0.124	0.126
1T4-11	-	-	-	-	0.071	0.089	0.047
1T4-12	-	-	-	-	0.071	0.100	0.041
1T4-13	-	-	-	-	0.063	0.083	0.037
1T4-14	-	-	-	-	0.068	0.121	0.037

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
= measurement not possible.

TABLE A-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITES (mV/m)
Small Mammals and Nesting Birds Studies
(page 4 of 4)

Site No., Meas. Pt.	1983 [a]	1984 [a]	1985 [a]	1986 [b]	1987 [c]	1988 [c]	1989 [d]
1D2-1	-	-	-	0.47	0.160	0.28	0.69
1T5-1	-	0.24,0.42	0.25	0.115	0.128	0.34	#
1T5-7	-	-	-	-	0.107	0.33	#
1T5-8	-	-	-	-	0.099	0.23	#
1T5-4	-	-	-	0.061	0.073	0.166	#
1T5-2	0.23	0.26	0.22	0.042	0.092	0.108	#
1T5-9	-	-	-	-	0.080	0.089	#
1T5-10	-	-	-	-	0.036	0.056	#
1T5-6	-	-	-	0.051	0.034	0.053	#
1T5-3	-	-	-	0.125	--	--	--
1T5-5	-	-	-	0.077	0.051	0.059	#
1T6-2	-	-	-	-	0.48	1.52	#
1T6-1	0.071	0.65-0.88	0.86,0.88	0.23	0.54	1.49	#
1T6-3	-	-	-	-	0.32	1.54	#
1T6-4	-	-	-	-	0.25	1.32	#
1T6-5	-	-	-	-	0.21	1.19	#
1T6-6	-	-	-	-	0.178	0.90	#
1T6-7	-	-	-	-	0.100	1.31	#

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
\# = measurement not possible.

TABLE A-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
(page 1 of 4)

Site No., Meas. Pt.	1983 [a]	1984 [a]	1985 [a]	1986 [b]	1987 [c]	1988 [c]	1989 [d]
1C1-2	<0.001	0.001	0.001	--	--	--	--
1C1-3	-	-	0.001	0.001	0.001	0.001	0.001
1C1-4	-	-	-	0.001	0.001	0.001	0.001
1C3-1	<0.001	0.002	0.002	0.001	0.001	0.001	0.001
1C3-2	0.001	0.003	/	--	--	--	--
1C3-3	-	-	-	0.001	0.001	0.001	0.001
1C4-1	-	<0.001,0.001	0.001	0.001	0.002	0.001	0.001
1C4-2	-	0.002	0.002	--	--	--	--
1C4-3	-	<0.001,0.002	<0.001	0.001	--	--	--
1C4-4	-	-	0.003	0.002	0.002	0.001	0.001
1C4-5	-	-	-	-	0.001	0.002	0.001
1D3-1	-	-	-	0.003	0.002	0.002	0.013
1C6-1	-	0.003	0.003	0.002	<0.001	0.002	0.003
1C6-3	-	-	0.003	0.003	0.003	0.002	0.002
1C6-4	-	-	0.003	0.003	0.004	0.003	0.003
1L1-4	-	-	-	0.114	0.118	0.078	0.075
1L4-1	-	-	-	-	-	0.003	0.002

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
\# = measurement not possible.

TABLE A-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
(page 2 of 4)

Site No., Meas. Pt.	a 1983	a 1984	a 1985	b 1986	c 1987	c 1988	d 1989
1T1-1	0.002	0.002	0.002	--	--	--	--
1T1-3	-	0.002	0.002	--	--	--	--
1T1-4	-	0.002	0.002	--	--	--	--
1T1-10	-	0.004	0.003	--	--	--	--
1T1-12	-	-	0.004	--	--	--	--
1T1-13	-	-	0.005	--	--	--	--
1T1-14	-	-	-	0.004	0.003	0.014	0.003
1T1-15	-	-	-	0.004	0.004	0.009	#
1T1-16	-	-	-	0.009	0.006	0.22	#
1T1-17	-	-	-	0.007	0.009	0.031	#
1T1-18	-	-	-	0.006	0.008	0.028	#
1T1-19	-	-	-	0.001	0.009	0.032	#
1T1-20	-	-	-	0.008	0.011	0.034	#
1T1-28	-	-	-	-	-	0.001	#
1T1-29	-	-	-	-	-	0.001	#
1T1-30	-	-	-	-	-	0.001	#
1T1-31	-	-	-	-	-	0.001	#
1T1-21	-	-	-	0.055	0.042	0.29	0.072
1T1-22	-	-	-	0.012	0.018	0.108	0.029
1T1-23	-	-	-	0.008	0.011	0.060	0.015
1T1-24	-	-	-	0.005	0.008	0.041	0.008
1T1-25	-	-	-	0.005	0.005	0.030	0.007
1T1-26	-	-	-	0.003	0.004	0.021	0.005
1T1-27	-	-	-	0.002	0.003	0.014	0.004

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
\# = measurement not possible.

TABLE A-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
(page 3 of 4)

Site No., Meas. Pt.	1983 [a]	1984 [a]	1985 [a]	1986 [b]	1987 [c]	1988 [c]	1989 [d]
1T2-1	<0.001	0.001	0.001	0.077	--	--	--
1T2-2	-	-	-	0.009	--	--	--
1T2-3	-	-	-	0.006	--	--	--
1T2-4	-	-	-	0.006	--	--	--
1T2-5	-	-	-	-	0.050	0.023	0.017
1T2-6	-	-	-	-	0.018	0.011	0.006
1T2-7	-	-	-	-	0.009	0.007	0.003
1T2-8	-	-	-	-	0.006	0.005	0.002
1T2-9	-	-	-	-	0.005	0.006	0.002
1D1-1	-	-	-	0.109	0.154	0.040	0.151
1T4-1	-	0.001	0.001	--	--	--	--
1T4-3	-	-	0.001	--	--	--	--
1T4-4	-	-	0.001	--	--	--	--
1T4-5	-	-	-	0.021	0.060	0.061	0.010
1T4-6	-	-	-	0.019	0.024	0.017	0.004
1T4-7	-	-	-	0.011	0.013	0.010	0.003
1T4-8	-	-	-	0.006	0.008	0.005	0.001
1T4-9	-	-	-	0.004	0.006	0.004	0.001
1T4-10	-	-	-	-	0.051	0.041	0.039
1T4-11	-	-	-	-	0.023	0.013	0.004
1T4-12	-	-	-	-	0.013	0.010	0.002
1T4-13	-	-	-	-	0.009	0.007	0.001
1T4-14	-	-	-	-	0.007	0.007	0.001

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
= measurement not possible.

TABLE A-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
(page 4 of 4)

Site No., Meas. Pt.	1983 [a]	1984 [a]	1985 [a]	1986 [b]	1987 [c]	1988 [c]	1989 [d]
1D2-1	-	-	-	0.004	0.006	0.005	0.005
1T5-1	-	0.001,0.002	0.001	0.051	0.071	0.159	#
1T5-7	-	-	-	-	0.039	0.077	#
1T5-8	-	-	-	-	0.016	0.025	#
1T5-4	-	-	-	0.006	0.008	0.016	#
1T5-2	0.001	0.002	0.001	0.038	0.042	0.075	#
1T5-9	-	-	-	-	0.019	0.028	#
1T5-10	-	-	-	-	0.011	0.017	#
1T5-6	-	-	-	0.004	0.008	0.012	#
1T5-3	-	-	-	0.007	--	--	--
1T5-5	-	-	-	0.005	0.019	0.018	#
1T6-2	-	-	-	-	0.111	0.34	#
1T6-1	0.002	0.001	0.001	0.020	0.058	0.134	#
1T6-3	-	-	-	-	0.020	0.061	#
1T6-4	-	-	-	-	0.014	0.044	#
1T6-5	-	-	-	-	0.011	0.033	#
1T6-6	-	-	-	-	0.008	0.023	#
1T6-7	-	-	-	-	0.008	0.022	#

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
\# = measurement not possible.

TABLE A-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
(page 1 of 3)

SITE NO., MEAS.PT.	1986				1987		1988		1989
	NS 4 amps	NEW 6 amps	SEW 6 amps	SEW 10 amps (EX)	NS 15 amps	EW 15 amps	NS 75 amps	EW 75 amps	B 150 amps
1C1-3	<	<	<	*	<	<	<	<	<
1C1-4	<	<	<	*	<	<	<	<	<
1C3-1	<	<	<	*	<	<	<	<	<
1C3-3	<	<	<	*	<	<	<	<	<
1C4-1	<	<	<	*	<	<	<	<	<
1C4-4	<	<	<	*	<	<	<	<	<
1C4-5	-	-	-	-	<	<	<	<	<
1D3-1	<	<	<	*	<	<	<	<	<
1C6-1	<	<	<	*	<	<	<	<	<
1C6-3	<	<	<	*	<	<	<	<	<
1C6-4	<	<	<	*	<	<	<	<	<
1L1-4	<	<	<	<	<	<	<	<	<
1L4-1	-	-	-	-	-	-	<	<	<
1T1-14	<	<	<	*	0.004	<	0.017	<	0.036
1T1-15	<	<	<	*	0.001	<	0.007	<	0.015
1T1-16	<	<	<	*	0.004	<	0.012	<	0.043

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

- = measurement point not established.
< = est. <0.001 V/m based on E-field in ground.
* = data cannot be extrapolated.

TABLE A-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
(page 2 of 3)

	1986				1987		1988		1989
SITE NO., MEAS.PT.	NS 4 amps	NEW 6 amps	SEW 6 amps	SEW 10 amps (EX)	NS 15 amps	EW 15 amps	NS 75 amps	EW 75 amps	B 150 amps
1T1-17	0.002	<	<	*	0.004	<	0.023	<	0.043
1T1-18	0.001	<	<	*	0.004	<	0.023	<	0.052
1T1-19	0.002	<	<	*	0.005	<	0.032	<	0.055
1T1-20	0.002	<	<	*	0.004	<	0.025	<	0.057
1T1-28	-	-	-	-	-	-	0.016	<	0.043
1T1-29	-	-	-	-	-	-	0.013	<	0.032
1T1-30	-	-	-	-	-	-	0.017	<	0.037
1T1-31	-	-	-	-	-	-	0.016	<	0.035
1T1-21	1.08	<	<	*	3.6	0.005	15.7	0.054	32
1T1-22	0.002	<	<	*	0.005	<0.001	0.024	<	0.049
1T1-23	<	<	<	*	0.008	<	0.033	<	0.053
1T1-24	<	<	<	*	0.013	<	0.045	<	0.150
1T1-25	<	<	<	*	0.019	<	0.059	<	0.160
1T1-26	<	<	<	*	0.012	<	0.044	<	0.092
1T1-27	<	<	<	*	0.008	<	0.032	<	0.060
1T2-5	-	-	-	-	1.28	0.014	7.3	0.100	11.1
1T2-6	-	-	-	-	0.169	0.002	0.84	0.013	1.17
1T2-7	-	-	-	-	0.034	<0.001	0.29	0.004	0.25
1T2-8	-	-	-	-	0.014	<	0.084	0.004	0.104
1T2-9	-	-	-	-	0.008	<	0.035	0.004	0.077
1D1-1	<	<	<	*	<	<	<	<	0.007
1T4-5	0.58	<	<	*	2.1	0.003	8.7	0.044	17.6
1T4-6	0.091	<	<	*	0.31	<0.001	1.76	0.009	4.2
1T4-7	0.022	<	<	*	0.089	<	0.35	0.003	0.69
1T4-8	0.005	<	<	*	0.014	<	0.054	0.002	0.093
1T4-9	0.002	<	<	*	0.008	<	0.045	0.002	0.081

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

- = measurement point not established.
< = est. <0.001 V/m based on E-field in ground.
* = data cannot be extrapolated.

TABLE A-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
(page 3 of 3)

	1986				1987		1988		1989
SITE NO., MEAS.PT.	NS 4 amps	NEW 6 amps	SEW 6 amps	SEW 10 amps (EX)	NS 15 amps	EW 15 amps	NS 75 amps	EW 75 amps	B 150 amps
1T4-10	-	-	-	-	1.30	0.001	6.4	0.033	12.3
1T4-11	-	-	-	-	0.30	<0.001	1.48	0.008	2.4
1T4-12	-	-	-	-	0.090	<0.001	0.39	0.003	0.69
1T4-13	-	-	-	-	0.033	<0.001	0.115	0.002	0.33
1T4-14	-	-	-	-	0.015	<0.001	0.066	0.002	0.128
1D2-1	<	<	<	*	<	0.003	0.001	0.001	0.011
1T5-1	0.81	<	<	*	3.1	0.005	12.4	0.040	26
1T5-7	-	-	-	-	0.54	0.001	1.78	0.005	5.2
1T5-8	-	-	-	-	0.008	<0.001	0.039	<	0.079
1T5-4	0.002	<	<	*	0.007	<	0.039	<	0.066
1T5-2	0.59	<	<	*	2.9	0.003	15.8	0.056	23
1T5-9	-	-	-	-	0.44	<0.001	1.95	0.007	3.4
1T5-10	-	-	-	-	0.076	<	0.29	0.001	0.63
1T5-6	0.009	<	<	*	0.022	<	0.135	<	0.23
1T5-5	0.005	<	<	*	0.019	<	0.095	0.001	0.178
1T6-2	-	-	-	-	3.2	0.005	14.3	0.054	31
1T6-1	0.182	<	<	*	0.48	<	2.4	0.010	4.9
1T6-3	-	-	-	-	0.042	<0.001	0.121	<0.001	0.35
1T6-4	-	-	-	-	0.029	<0.001	0.122	<0.001	0.23
1T6-5	-	-	-	-	0.021	<0.001	0.107	<0.001	0.153
1T6-6	-	-	-	-	0.019	<0.001	0.075	<0.001	0.151
1T6-7	-	-	-	-	0.015	<0.001	0.079	0.001	0.142

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

- = measurement point not established.
< = est. <0.001 *V/m based on E-field in ground.*
* = data cannot be extrapolated.

TABLE A-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
(page 1 of 3)

SITE NO., MEAS.PT.	1986 NS 4 amps	1986 NEW 6 amps	1986 SEW 6 amps	1986 SEW 10 amps (EX)	1987 NS 15 amps	1987 EW 15 amps	1988 NS 75 amps	1988 EW 75 amps	1989 B 150 amps
1C1-3	0.021	0.003	0.010	0.017	0.082	0.028	0.44	0.139	1.31
1C1-4	/	/	/	/	0.087	0.033	0.42	0.185	1.70
1C3-1	/	/	/	/	0.050	0.025	0.26	0.119	0.74
1C3-3	0.022	0.004	0.012	0.020	0.086	0.032	0.41	0.157	1.18
1C4-1	/	/	/	/	0.005	0.004	0.023	0.019	0.070
1C4-4	<0.001	<0.001	<0.001	*	0.002	0.002	0.005	0.005	0.030
1C4-5	-	-	-	-	0.003	0.002	0.012	0.008	0.037
1D3-1	0.008	0.004	0.005	0.008	0.053	0.019	0.21	0.065	0.85
1C6-1	/	/	/	/	0.004	0.003	0.017	0.017	0.083
1C6-3	0.001	<0.001	0.001	0.002	0.008	0.004	0.026	0.016	0.110
1C6-4	/	/	/	/	0.003	0.002	0.017	0.009	0.045
1L1-4	/	/	/	/	/	/	/	/	#
1L4-1	-	-	-	-	-	-	0.006	0.002	0.013
1T1-14	0.86	0.026	0.021	0.035	3.1	0.069	18.1	0.21	34
1T1-15	0.43	0.013	0.015	0.025	1.60	0.051	9.2	0.21	13.6
1T1-16	1.11	0.035	0.035	0.058	4.6	0.133	24	0.61	47

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

- = measurement point not established.
/ = measurement not taken.
= measurement not possible.
* = data cannot be extrapolated.

TABLE A-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
(page 2 of 3)

	1986				1987		1988		1989
SITE NO., MEAS.PT.	NS 4 amps	NEW 6 amps	SEW 6 amps	SEW 10 amps (EX)	NS 15 amps	EW 15 amps	NS 75 amps	EW 75 amps	B 150 amps
1T1-17	1.55	0.049	0.053	0.088	6.2	0.139	23	0.57	43
1T1-18	1.44	0.042	0.050	0.083	5.6	0.166	26	0.71	49
1T1-19	1.54	0.050	0.053	0.088	6.4	0.142	28	0.69	57
1T1-20	1.45	0.046	0.043	0.072	6.0	0.142	28	0.77	56
1T1-28	-	-	-	-	-	-	25	0.74	54
1T1-29	-	-	-	-	-	-	16.1	0.58	35
1T1-30	-	-	-	-	-	-	17.2	0.63	39
1T1-31	-	-	-	-	-	-	20	0.71	41
1T1-21	1.45	0.044	0.009	0.015	7.4	0.026	31	0.133	54
1T1-22	1.50	0.042	0.009	0.015	4.2	0.021	25	0.62	41
1T1-23	0.96	0.030	0.003	0.005	2.9	0.017	18.7	0.109	33
1T1-24	1.15	0.036	0.010	0.017	4.7	0.020	14.8	0.117	59
1T1-25	0.87	0.027	0.062	0.103	2.9	0.019	15.6	0.079	33
1T1-26	0.56	0.017	0.004	0.007	2.0	0.014	12.3	0.082	23
1T1-27	0.38	0.012	0.004	0.007	1.82	0.015	6.2	0.057	19.3
1T2-5	-	-	-	-	8.7	0.77	39	3.1	85
1T2-6	-	-	-	-	8.5	0.86	41	4.6	86
1T2-7	-	-	-	-	7.0	0.56	31	2.7	70
1T2-8	-	-	-	-	7.1	0.66	31	3.6	70
1T2-9	-	-	-	-	6.2	0.79	31	3.6	70
1D1-1	0.042	0.28	0.066	0.110	0.23	0.67	1.15	3.4	7.6
1T4-5	2.1	0.062	0.054	0.090	6.4	0.191	34	0.76	84
1T4-6	2.5	0.076	0.103	0.172	6.3	0.29	45	1.35	87
1T4-7	2.2	0.067	0.092	0.153	8.7	0.30	37	1.40	76
1T4-8	1.91	0.061	0.123	0.21	7.7	0.31	32	1.59	72
1T4-9	2.1	0.062	0.126	0.21	6.2	0.34	35	1.74	55

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

\- = measurement point not established.
/ = measurement not taken.
= measurement not possible.
* = data cannot be extrapolated.

TABLE A-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
(page 3 of 3)

	1986				1987		1988		1989
SITE NO., MEAS.PT.	NS 4 amps	NEW 6 amps	SEW 6 amps	SEW 10 amps (EX)	NS 15 amps	EW 15 amps	NS 75 amps	EW 75 amps	B 150 amps
1T4-10	-	-	-	-	12.4	0.29	47	1.30	86
1T4-11	-	-	-	-	6.4	0.27	34	1.26	83
1T4-12	-	-	-	-	7.4	0.38	39	1.31	76
1T4-13	-	-	-	-	5.7	0.33	29	1.60	70
1T4-14	-	-	-	-	6.7	0.33	31	1.56	55
1D2-1	0.094	0.44	0.113	0.188	0.41	1.36	1.58	4.8	9.7
1T5-1	2.6	0.079	0.074	0.123	9.7	0.21	47	0.94	110
1T5-7	-	-	-	-	8.4	0.21	48	1.01	78
1T5-8	-	-	-	-	8.2	0.20	38	0.87	90
1T5-4	1.39	0.042	0.061	0.102	5.8	0.21	29	0.98	61
1T5-2	1.97	0.064	0.108	0.180	8.2	0.23	24	0.77	70
1T5-9	-	-	-	-	7.2	0.29	19.5	0.84	47
1T5-10	-	-	-	-	3.4	0.170	14.4	1.00	36
1T5-6	1.08	0.037	0.070	0.117	3.3	0.21	13.1	0.98	32
1T5-5	1.31	0.051	0.101	0.168	5.2	0.33	23	1.40	45
1T6-2	-	-	-	-	27.	0.24	71	0.79	250
1T6-1	5.4	0.159	0.086	0.143	32.	0.25	102	1.03	169
1T6-3	-	-	-	-	21.	0.144	97	0.67	187
1T6-4	-	-	-	-	16.3	0.122	87	0.61	139
1T6-5	-	-	-	-	15.3	0.22	80	1.27	143
1T6-6	-	-	-	-	11.6	0.132	63	0.66	128
1T6-7	-	-	-	-	6.0	0.178	87	1.41	120

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

\- = measurement point not established.
/ = measurement not taken.
= measurement not possible.
* = data cannot be extrapolated.

TABLE A-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
(page 1 of 3)

SITE NO., MEAS. PT.	1986 NS 4 amps	1986 NEW 6 amps	1986 SEW 6 amps	1986 SEW 10 amps (EX)	1987 NS 15 amps	1987 EW 15 amps	1988 NS 75 amps	1988 EW 75 amps	1989 B 150 amps
1C1-3	<0.001	<0.001	<0.001	*	0.001	<0.001	0.003	0.001	0.007
1C1-4	/	/	/	/	0.001	<0.001	0.003	0.001	0.006
1C3-1	/	/	/	/	0.001	<0.001	0.003	0.001	0.008
1C3-3	<0.001	<0.001	<0.001	*	0.001	<0.001	0.003	0.001	0.007
1C4-1	/	/	/	/	<0.001	<0.001	0.001	<0.001	0.001
1C4-4	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002
1C4-5	-	-	-	-	<0.001	<0.001	0.001	<0.001	0.002
1D3-1	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.002	0.002	0.008
1C6-1	/	/	/	/	<0.001	<0.001	0.001	0.001	0.004
1C6-3	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	0.001	0.004
1C6-4	/	/	/	/	<0.001	<0.001	0.002	0.001	0.005
1L1-4	/	/	/	/	<0.001	<0.001	/	/	<0.001
1L4-1	-	-	-	-	-	-	<0.001	<0.001	0.002
1T1-14	0.032	0.001	0.001	0.002	0.115	0.003	0.65	0.014	1.35
1T1-15	0.027	0.001	0.001	0.002	0.097	0.003	0.47	0.012	1.01
1T1-16	0.069	0.002	0.001	0.002	0.22	0.002	1.05	0.013	2.1

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

\- = measurement point not established.
/ = measurement not taken.
* = data cannot be extrapolated.

TABLE A-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
(page 2 of 3)

	1986				1987		1988		1989
SITE NO., MEAS.PT.	NS 4 amps	NEW 6 amps	SEW 6 amps	SEW 10 amps (EX)	NS 15 amps	EW 15 amps	NS 75 amps	EW 75 amps	B 150 amps
1T1-17	0.076	0.003	0.001	0.002	0.23	0.001	1.49	0.012	2.9
1T1-18	0.071	0.002	0.001	0.002	0.27	0 002	1.28	0.012	2.6
1T1-19	0.081	0.003	0.001	0.002	0.32	0.002	1.51	0.013	3.1
1T1-20	0.089	0.003	0.001	0.002	0.36	0.002	1.68	0.013	3.3
1T1-28	-	-	-	-	-	-	1.25	0.015	2.4
1T1-29	-	-	-	-	-	-	1.10	0.015	2.1
1T1-30	-	-	-	-	-	-	1.12	0.015	2.3
1T1-31	-	-	-	-	-	-	1.00	0.015	2.1
1T1-21	0.78	0.024	0.004	0.007	2.9	0.005	13.8	0.043	32
1T1-22	0.31	0.010	0.002	0.003	1.16	0.016	5.8	0.019	12.3
1T1-23	0.169	0.005	0.001	0.002	0.64	0.003	3.0	0.013	6.6
1T1-24	0.113	0.004	0.001	0.002	0.43	0.003	2.1	0.011	4.3
1T1-25	0.084	0.003	0.007	0.012	0.32	0.003	1.52	0.011	3.4
1T1-26	0.055	0.002	0.001	0.002	0.21	0.002	1.00	0.010	2.2
1T1-27	0.040	0.012	0.001	0.002	0.149	0.002	0.69	0.009	1.51
1T2-5	-	-	-	-	3.2	0.005	15.1	0.053	33
1T2-6	-	-	-	-	1.23	0.003	5.8	0.031	12.0
1T2-7	-	-	-	-	0.64	0.002	3.1	0.023	6.4
1T2-8	-	-	-	-	0.43	0.003	2.1	0.020	4.3
1T2-9	-	-	-	-	0.32	0.003	1.59	0.019	3.3
1D1-1	<0.001	0.003	0.001	0.002	0.001	0.011	0.004	0.053	0.102
1T4-5	0.70	0.022	0.004	0.007	2.9	0.004	13.4	0.047	29
1T4-6	0.32	0.010	0.002	0.003	1.21	0.002	5.7	0.025	12.6
1T4-7	0.171	0.005	0.001	0.002	0.66	0.001	3.1	0.017	6.4
1T4-8	0.116	0.003	0.001	0.002	0.43	0.002	2.1	0.014	4.3
1T4-9	0.085	0.003	0.001	0.002	0.34	0.002	1.55	0.012	3.2

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = *extrapolated data.*

\- = measurement point not established.
/ = measurement not taken.
* = data cannot be extrapolated.

TABLE A-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
(page 3 of 3)

	1986				1987		1988		1989
SITE NO., MEAS.PT.	NS 4 amps	NEW 6 amps	SEW 6 amps	SEW 10 amps (EX)	NS 15 amps	EW 15 amps	NS 75 amps	EW 75 amps	B 150 amps
1T4-10	-	-	-	-	2.7	0.004	16.5	0.042	26
1T4-11	-	-	-	-	0.87	0.003	5.3	0.015	11.7
1T4-12	-	-	-	-	0.64	0.002	2.9	0.008	6.3
1T4-13	-	-	-	-	0.43	0.002	2.0	0.007	4.3
1T4-14	-	-	-	-	0.32	0.002	1.55	0.006	3.2
1D2-1	<0.001	0.003	0.001	0.002	0.002	0.008	0.009	0.043	0.077
1T5-1	0.89	0.029	0.005	0.008	3.6	0.005	17.0	0.059	34
1T5-7	-	-	-	-	1.93	0.002	8.9	0.035	18.9
1T5-8	-	-	-	-	0.75	0.001	3.5	0.017	7.3
1T5-4	0.124	0.004	0.001	0.002	0.46	0.001	2.2	0.013	4.5
1T5-2	0.77	0.024	0.004	0.007	3.1	0.004	14.4	0.052	31
1T5-9	-	-	-	-	1.18	0.003	5.6	0.017	11.7
1T5-10	-	-	-	-	0.67	0.002	3.2	0.009	6.1
1T5-6	0.125	0.004	<0.001	*	0.46	0.002	2.1	0.007	4.5
1T5-5	0.131	0.004	0.001	0.002	0.53	0.001	2.5	0.014	5.1
1T6-2	-	-	-	-	3.9	0.006	17.8	0.061	35
1T6-1	0.40	0.013	0.002	0.003	1.51	0.004	7.2	0.021	14.7
1T6-3	-	-	-	-	0.65	0.002	3.2	0.008	6.5
1T6-4	-	-	-	-	0.44	0.002	2.1	0.006	4.7
1T6-5	-	-	-	-	0.34	0.002	1.70	0.004	3.5
1T6-6	-	-	-	-	0.24	0.016	1.17	0.004	2.4
1T6-7	-	-	-	-	0.22	0.002	1.05	0.005	2.1

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

- = measurement point not established.
/ = measurement not taken.
* = data cannot be extrapolated.

TABLE A-8. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies Laboratory

Site No., Meas. Pt.	1989	1990 Before Shielding	1990 After Shielding
1L1-5	#	#	#
1L1-6	#	#	#
1L1-7	8.1	8.5	1.34
1L1-8	0.88	0.76	0.037
1L1-9	60	18.1	3.9*
1L1-10	-	/	0.010

= measurement not possible.
- = measurement point not established.
/ = measurement not taken.
* = 4.0 V/m with humidifier on.

TABLE A-9. *60 Hz MAGNETIC FLUX DENSITIES (mG)*
Small Mammals and Nesting Birds Studies Laboratory

Site No., Meas. Pt.	1989	1990
1L1-5	14.1[1]	5.2[3]
	21.0[2]	0.62[4]
1L1-6	3.2[1]	2.4[3]
	44.0[2]	0.195[4]
		0.081[5]
1L1-7	0.65	1.69
1L1-8	1.46	0.88
1L1-9	48.0	0.86
1L1-10	-	0.75

[1] = measurement made in vertical orientation only in an open, unshielded can, submerged to its rim.
[2] = measurement made above the bath surface.
[3] = measurement made in closed, unshielded, fully submerged can.
[4] = measurement made in closed, shielded, fully submerged can.
[5] = measurement made in closed, shielded, fully submerged can with motor and pump shielding (final configuration; see Figure A-38).
- = measurement point not established.

APPENDIX B

NATIVE BEES STUDIES

NATIVE BEES STUDIES

During May and September, 1989, IITRI field crews made ELF electromagnetic (EM) field measurements at 22 measurement points at two treatment and two control sites, the Crystal Falls laboratory, and the remote holding facility for the native bees studies. The treatment and control site measurement points were the same as those used in 1988. In 1989, three new measurement points (2L1-4, 2L1-5, 2L1-6) were added at the Crystal Falls laboratory, and one new measurement point (2L2-1) was added at the remote holding facility where bees are kept prior to being examined in the laboratory. This remote holding facility is shared with researchers conducting the small mammals and nesting birds studies.

The positions of the six sites relative to the NRTF-Republic are shown on the composite map in Figure B-1. The site numbers listed on the map are those used by IITRI. Table B-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are given in Figures B-2 through B-9.

TABLE B-1. SITE NO. CROSS-REFERENCE
Native Bees Studies

IITRI Site No.	Investigator's Site Name	Location Township	: Range	: Section(s)
2T1	Ford 1 (F1)	T43N	: R29W	: 14
2T2	Ford 2 (F2)	T43N	: R29W	: 14
2C4	County Line Road (CL)	T43N	: R30W	: 19
2C5	Camp 5 (C5)	T42N	: R31W	: 13
2L1	Crystal Falls Laboratory	T43N	: R32W	: 29
2L2	Remote Holding Facility	T42N	: R32W	: 9

The native bees studies incorporate studies of both nesting and development traits. The electric and magnetic fields present in the air are considered the most important factors in the orientation and site tenacity of bees during their nesting cycle. The electric and magnetic fields in the earth near the surface may be of importance in developmental studies.

EM field measurements for 1989 and previous years are found in Tables B-2 through B-7. Tables B-2, B-3, and B-4 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables B-5, B-6, and B-7 present 76 Hz data for these three fields at the corresponding operating currents of the NRTF-Republic for each year.

In 1989, 60 Hz measurements were not made at treatment study sites because of modulated antenna operation. The 60 Hz EM fields measured at control study sites in 1989 were consistent with those measured in previous years.

The 60 Hz EM fields measured at the Crystal Falls laboratory remain significantly higher (up to 1000 times) than the 60 Hz fields measured at any of the study sites. Some of the laboratory 60 Hz air electric field exposures even exceed the 76 Hz exposures at the test sites. These relatively high intensities could mask differences caused by exposures at test and control sites. As recommended, the duration of exposure of nest boxes at the Crystal Falls laboratory has been minimized by using the remote holding facility, set up by the small mammals and nesting birds studies researchers, for temporary nest storage. In addition, IITRI arranged to have wire-mesh cages built to shield the bees from 60 Hz air electric fields experienced at the Crystal Falls laboratory. These will be in place prior to the start of 1990 laboratory work.

The 1989 76 Hz measurements were made with 150 ampere antenna currents, the predominant operating current of the NRTF-Republic since 4 May 1989. The EM exposures at the study sites for the period prior to 4 May can be estimated either by using the 75 ampere antenna current measurement data from 1988 or by using one-half the value of the 1989 150 ampere data.

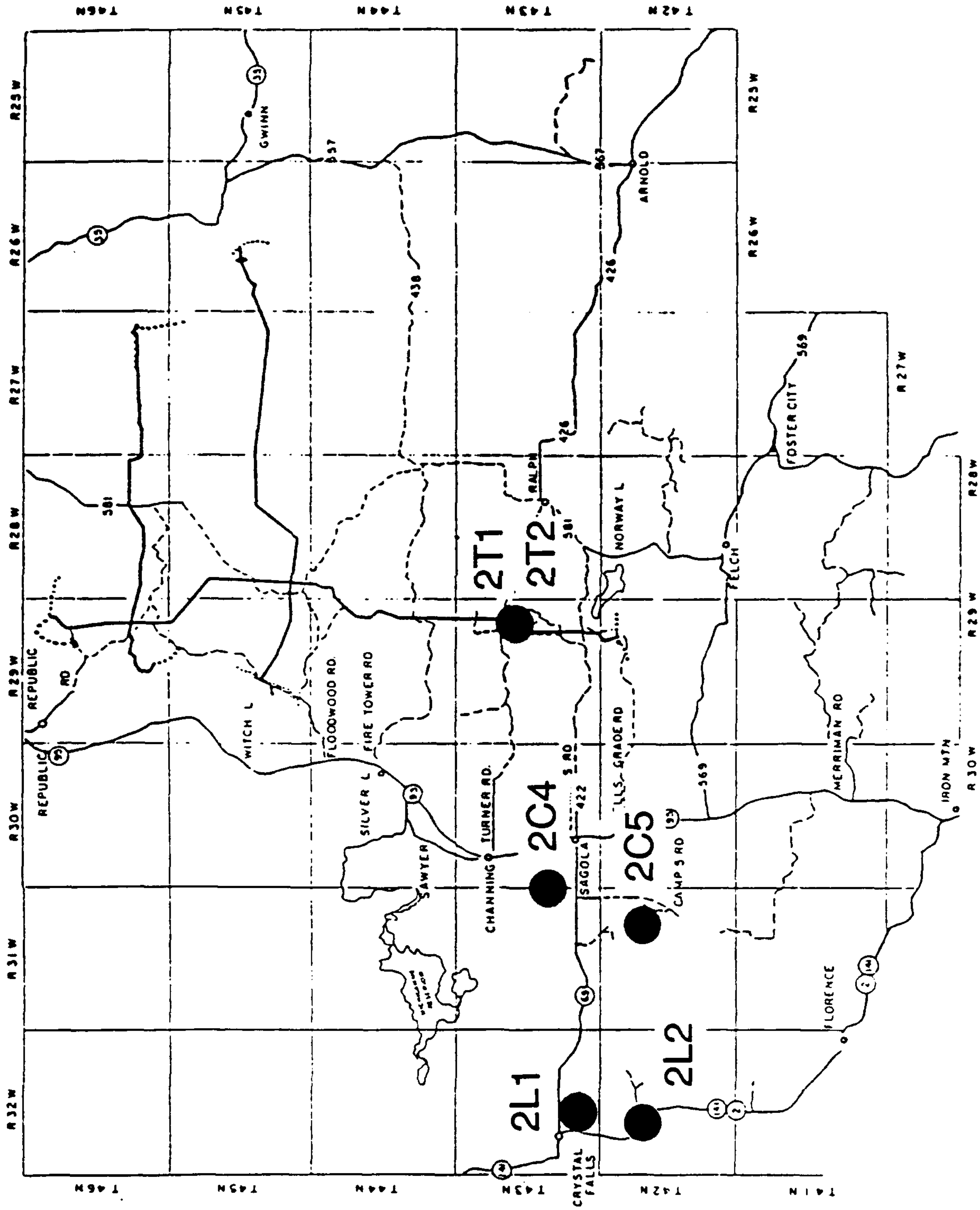


FIGURE B-1. POSITIONS OF NATIVE BEES STUDY SITES RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

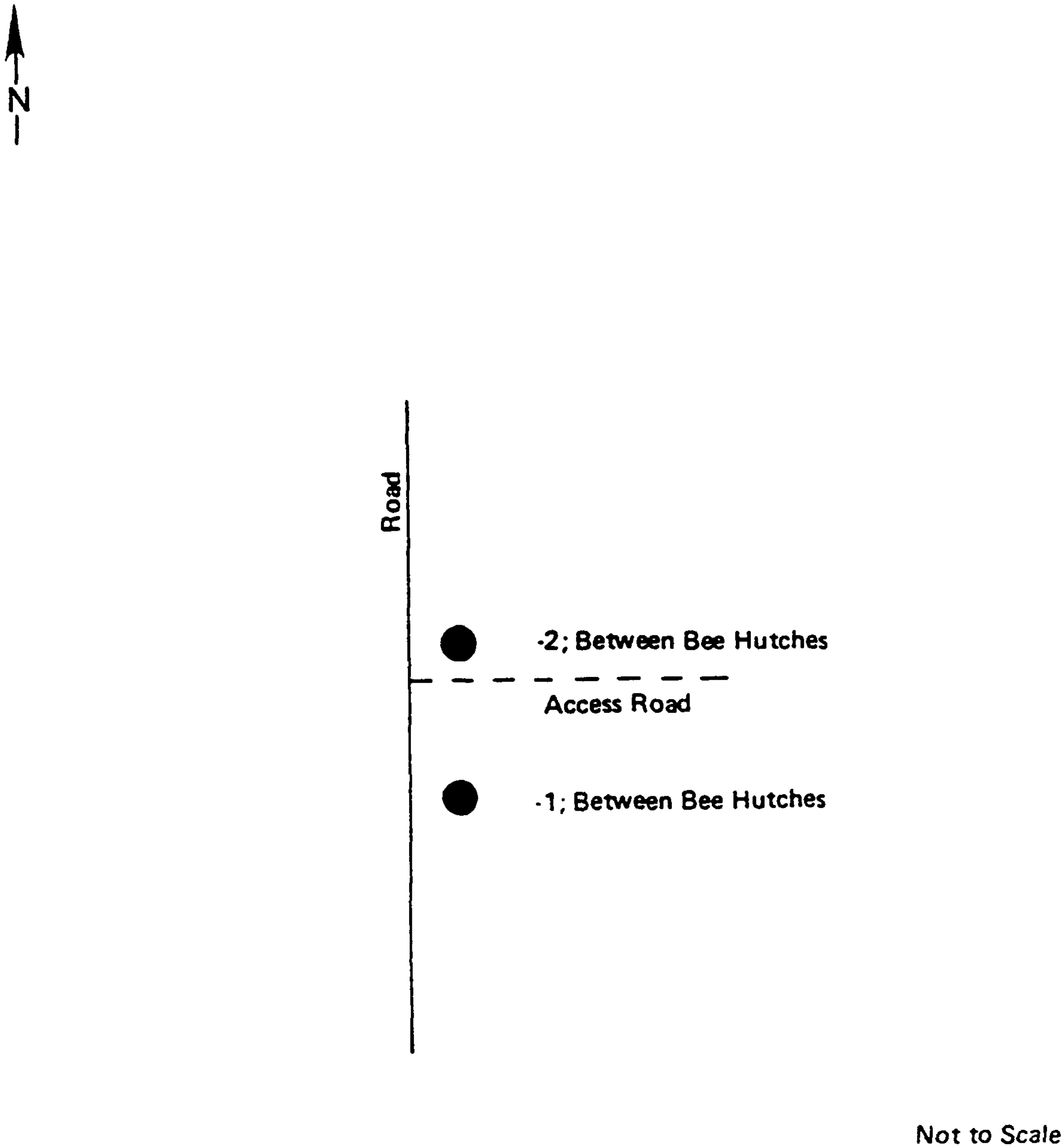


FIGURE B-2. MEASUREMENT POINTS AT COUNTY LINE ROAD (CL); 2C4-1, 2.

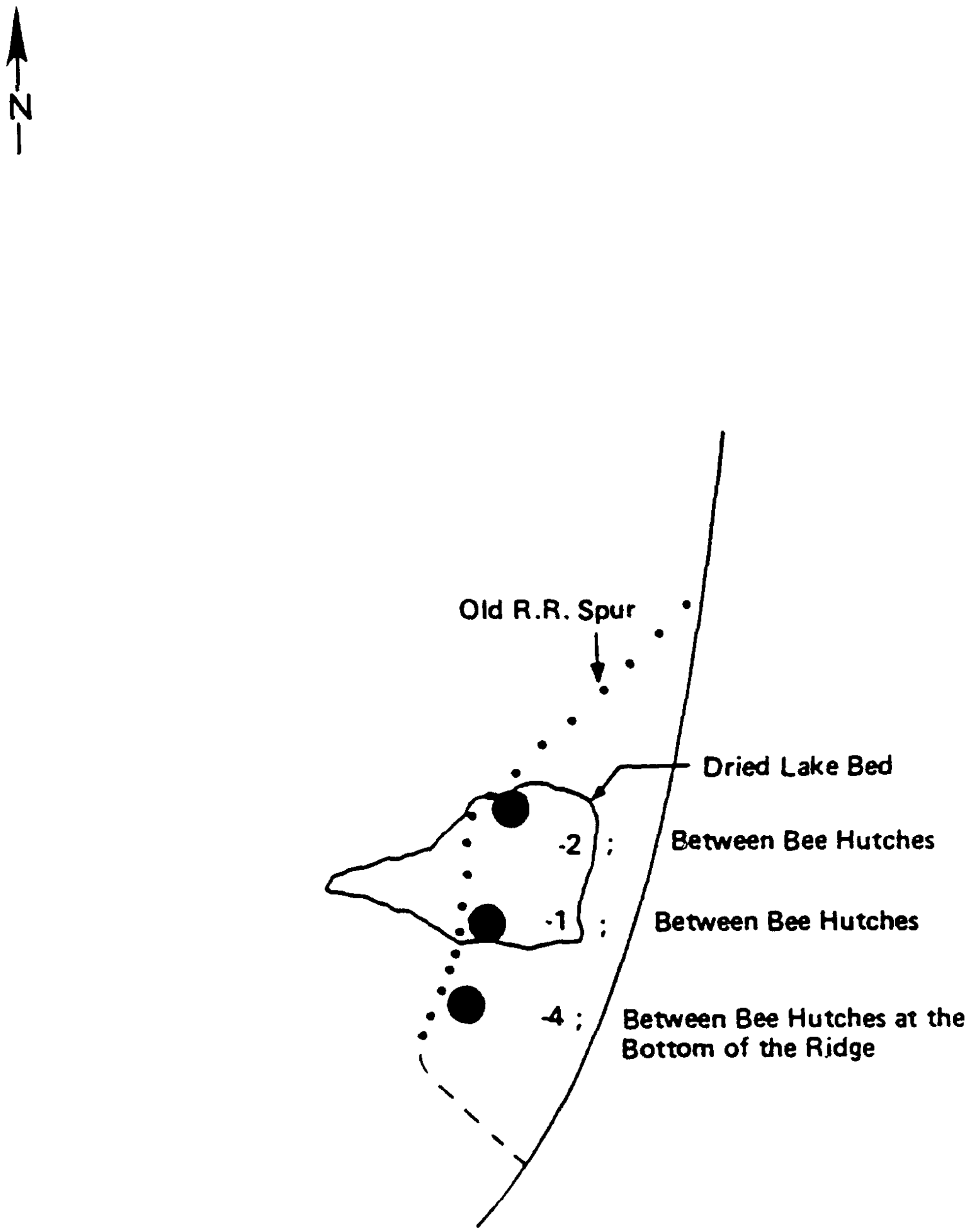


FIGURE B-3. MEASUREMENT POINTS AT CAMP 5 (C5); 2C5-1, 2, 4.

60297/790

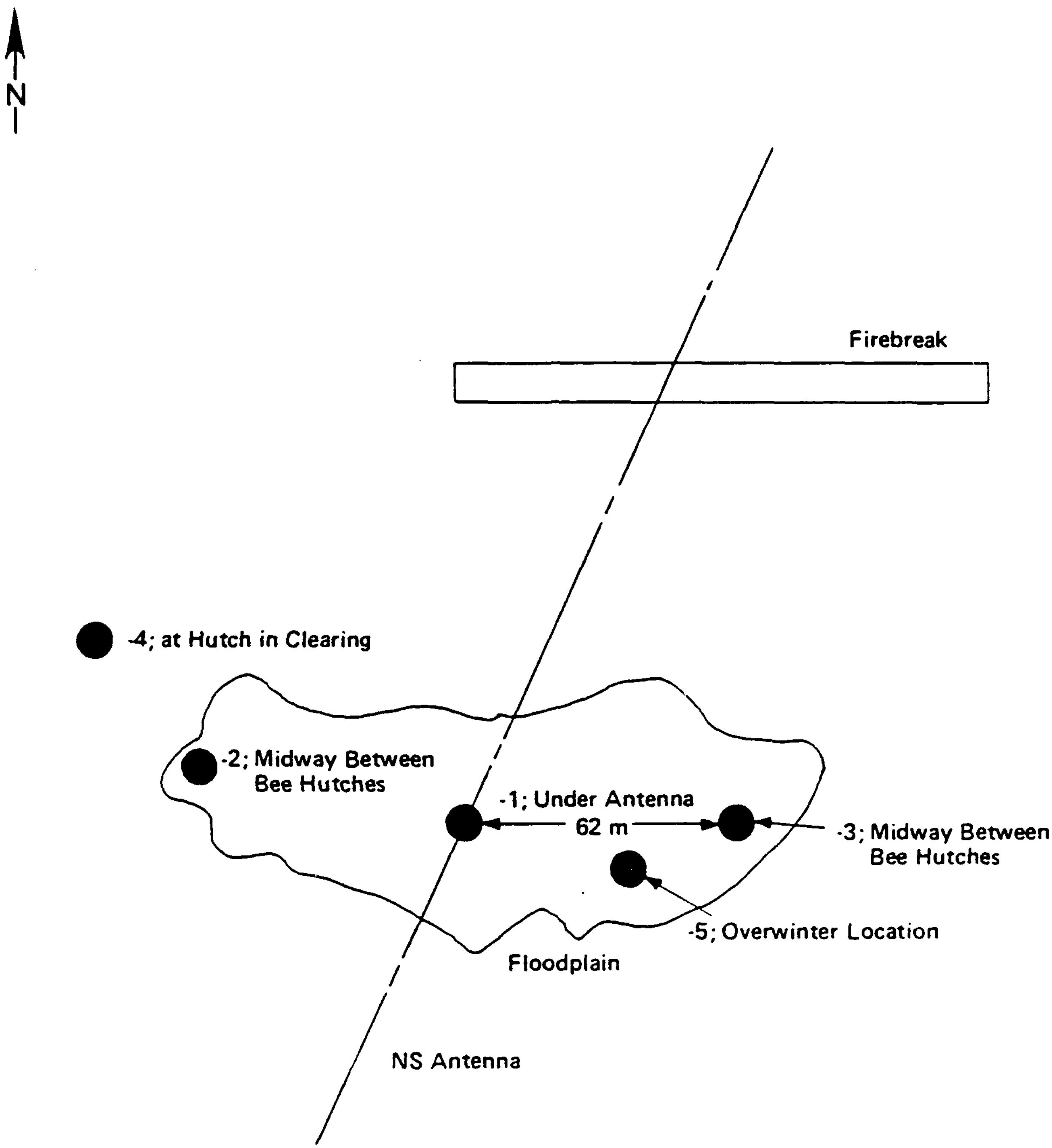


FIGURE B-4. MEASUREMENT POINTS AT FORD 1 (F1); 2T1-1 THROUGH 5.

60297/790

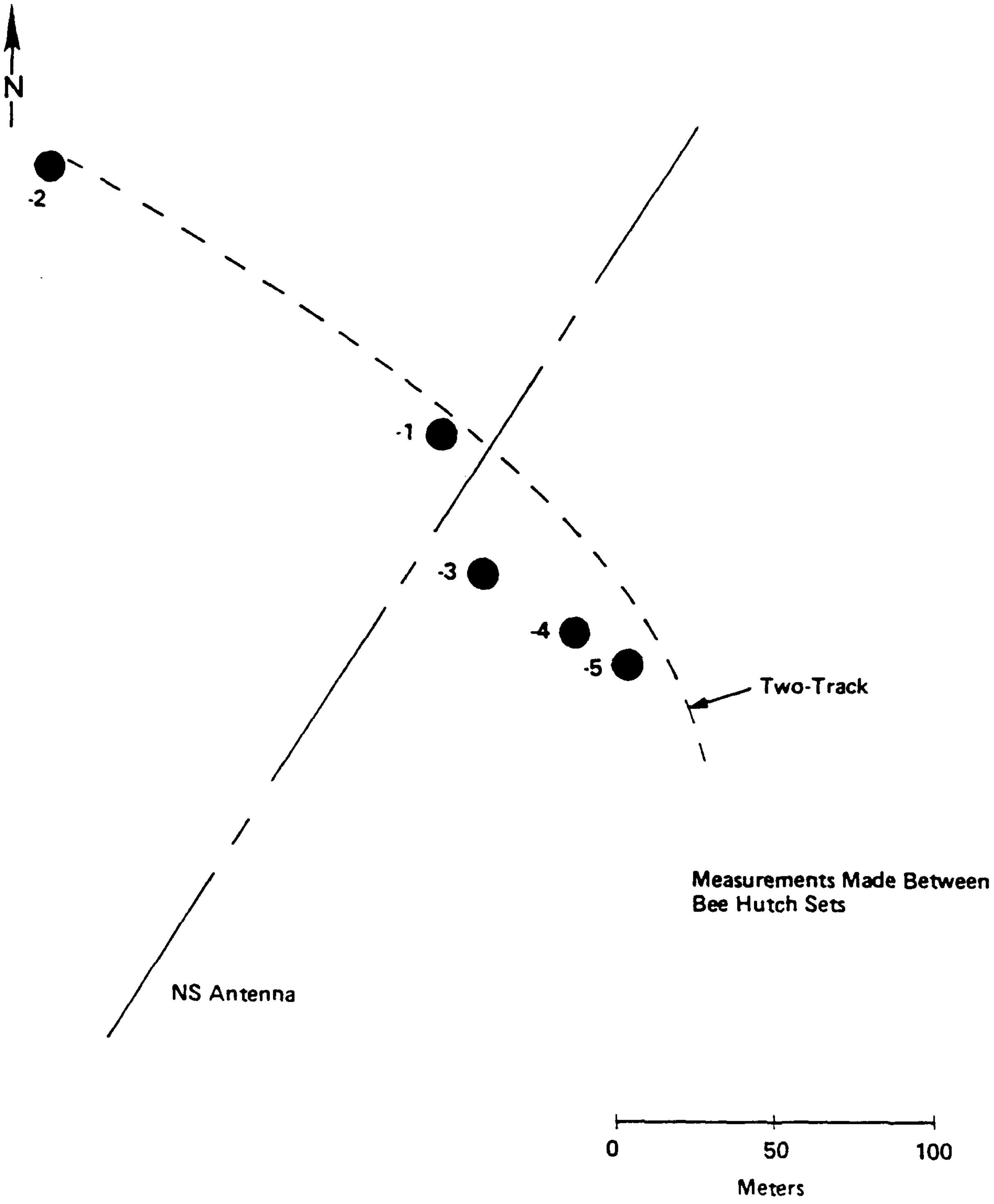


FIGURE B-5. MEASUREMENT POINTS AT FORD 2 (F2); 2T2-1 THROUGH 5.

60297/790

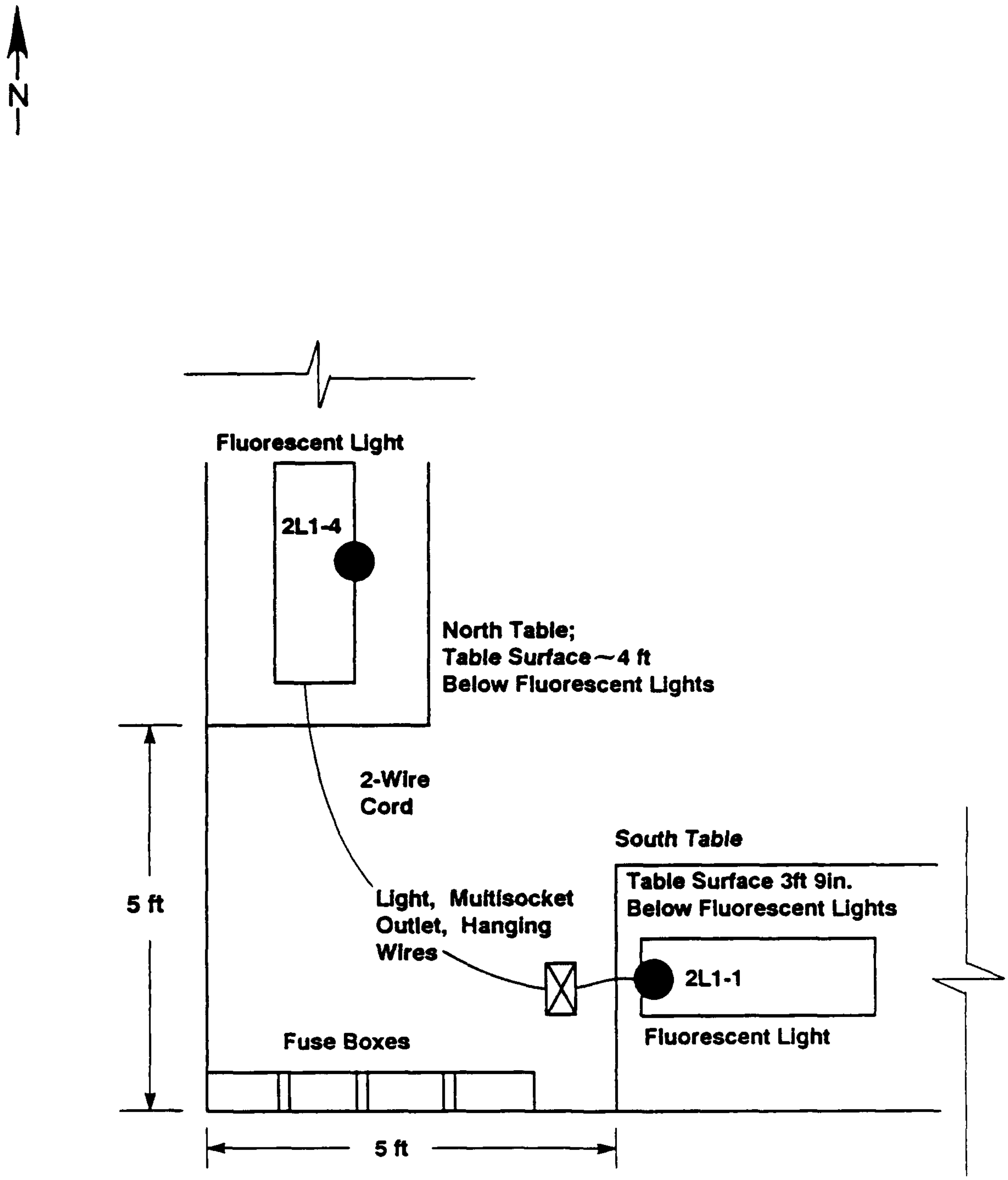


FIGURE B-6. MEASUREMENT POINTS AT CRYSTAL FALLS LABORATORY BASEMENT; 2L1-1, 2L1-4.

60297/190

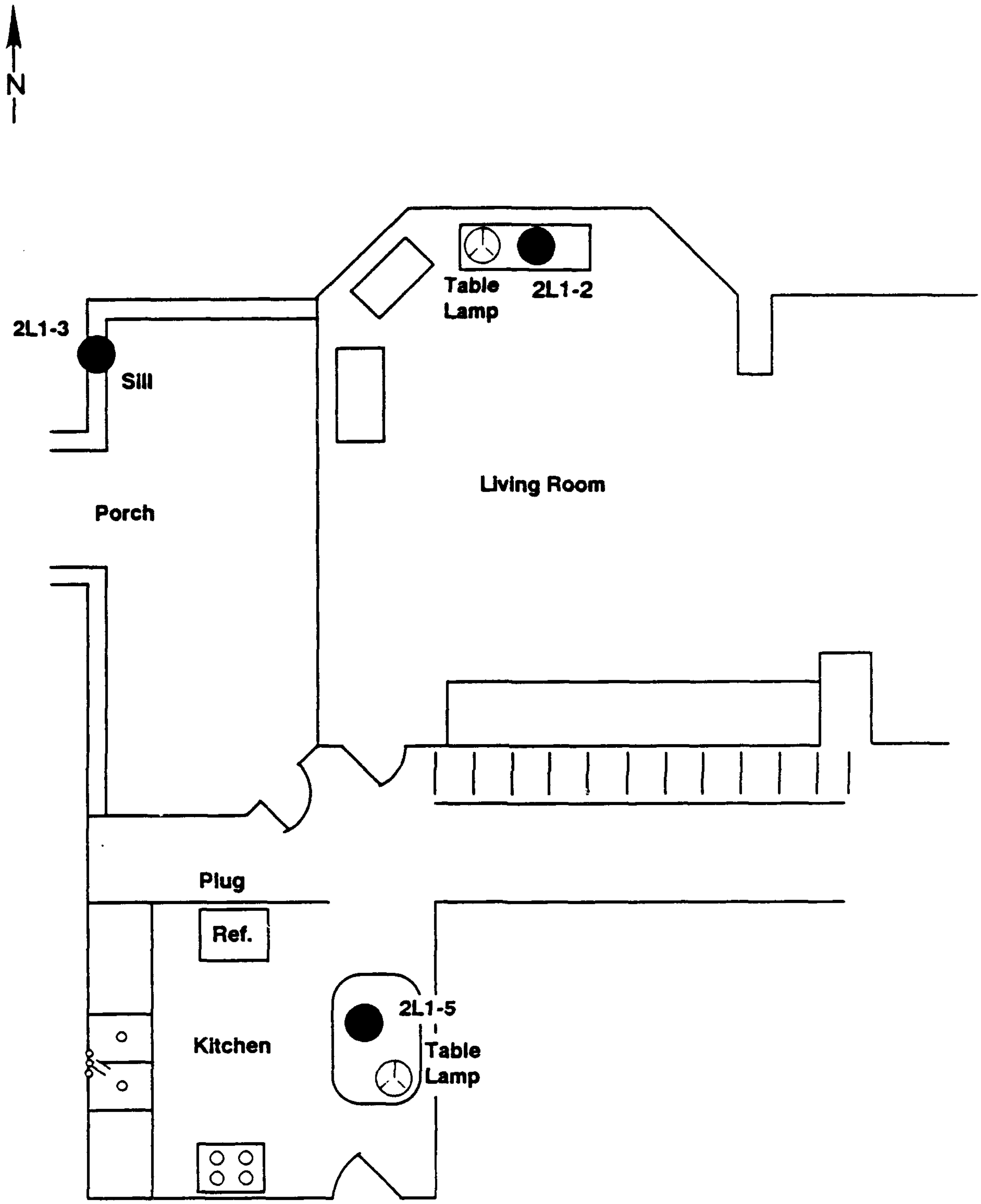


FIGURE B-7. MEASUREMENT POINTS AT CRYSTAL FALLS LABORATORY GROUND LEVEL; 2L1-2, 2L1-3, 2L1-5.

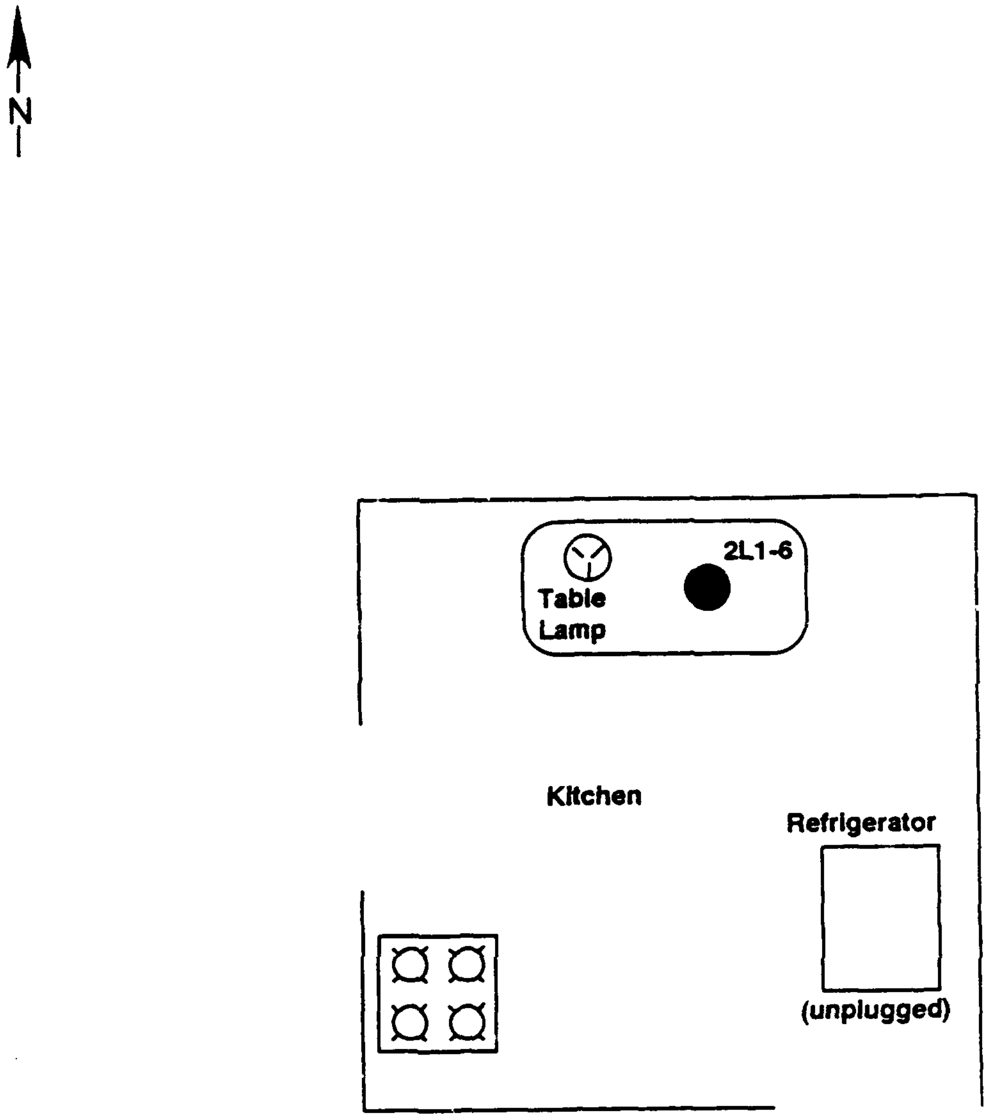


FIGURE B-8. MEASUREMENT POINT AT CRYSTAL FALLS LABORATORY SECOND FLOOR; 2L1-6.

60297/790

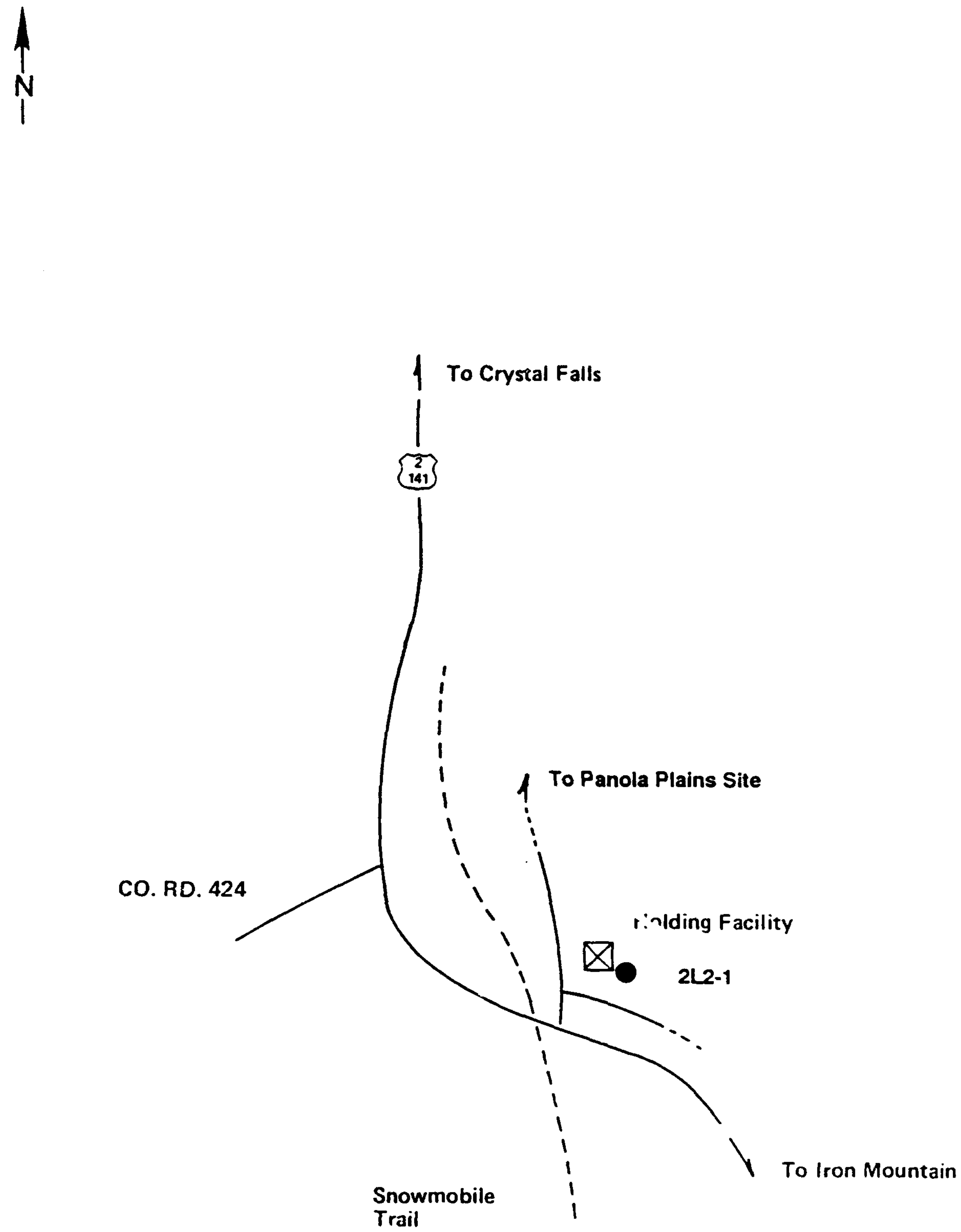


FIGURE B-9. MEASUREMENT POINT AT REMOTE HOLDING FACILITY; 2L2-1.

60297/790

TABLE B-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
NATIVE BEES STUDIES

Site No., Meas. Pt.	1983 [a]	1984 [a]	1985 [a]	1986 [b]	1987 [c]	1988 [c]	1989 [d]
2C4-1	<0.001	<0.001	<	<	<	<	<
2C4-2	-	-	<	<	<	<	<
2C5-1	-	<0.001	<	<	<	<	<
2C5-2	-	<0.001	<	<	<	<	<
2C5-4	-	-	<	<	<	<	<
2L1-1	-	-	-	-	-	79	31
2L1-2	-	-	-	-	-	22	19.5
2L1-3	-	-	-	-	-	0.25	0.45
2L1-4	-	-	-	-	-	-	12.5
2L1-5	-	-	-	-	-	-	18.2
2L1-6	-	-	-	-	-	-	5.3
2L2-1	-	-	-	-	-	<	<
2T1-1	0.004	<0.001	<	<	0.074	0.13	#
2T1-2	-	-	-	<	<0.001	0.001	#
2T1-3	-	-	-	<	<0.001	0.001	#
2T1-4	-	-	-	-	<	<0.001	#
2T1-5	-	-	-	-	<	0.006	#
2T2-1	<0.001	<0.001,0.001	<	<	0.024	0.079	#
2T2-2	-	-	-	<	<0.001	<0.001	#
2T2-3	-	-	-	<	0.023	0.087	#
2T2-4	-	-	-	<	0.003	0.012	#
2T2-5	-	-	-	<	0.002	0.005	#

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

- = measurement point not established.
= measurement not possible.
< = est. <0.001 V/m based on E-field in ground.

TABLE B-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITES (mV/m)
NATIVE BEES STUDIES

Site No., Meas. Pt.	1983 [a]	1984 [a]	1985 [a]	1986 [b]	1987 [c]	1988 [c]	1989 [d]
2C4-1	0.011	0.102, 0.138, 0.160	0.104	0.133	0.178	0.134	0.095
2C4-2	-	-	0.21	0.21	0.26	0.23	0.169
2C5-1	-	0.64, 0.50, 0.93	0.69	0.49	0.38	0.23	0.21
2C5-2	-	0.23	0.40	0.160	0.23	0.099	0.139
2C5-4	-	-	0.148	0.090	0.098	0.078	0.078
2L1-1	-	-	-	-	-	#	#
2L1-2	-	-	-	-	-	#	#
2L1-3	-	-	-	-	-	#	#
2L1-4	-	-	-	-	-	#	#
2L1-5	-	-	-	-	-	#	#
2L1-6	-	-	-	-	-	#	#
2L2-1	-	-	-	-	-	0.019	0.022,0.013
2T1-1	0.23	0.26	0.22	0.042	0.092	0.108	#
2T1-2	-	-	-	0.051	0.034	0.053	#
2T1-3	-	-	-	0.077	0.051	0.059	#
2T1-4	-	-	-	-	0.040	0.152	#
2T1-5	-	-	-	-	0.050	0.151	#
2T2-1	0.071	0.65,0.88	0.86,0.88	0.23	0.54	1.49	#
2T2-2	-	-	-	0.092	0.100	1.31	#
2T2-3	-	-	-	0.123	0.25	0.84	#
2T2-4	-	-	-	0.078	0.186	0.67	#
2T2-5	-	-	-	0.120	0.23	1.11	#

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

- = measurement point not established.
= measurement not possible.

TABLE B-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
NATIVE BEES STUDIES

Site No., Meas. Pt.	1983 a	1984 a	1985 a	1986 b	1987 c	1988 c	1989 d
2C4-1	0.004	0.003,0.004	0.003	0.003	0.006	0.006	0.005
2C4-2	-	-	0.003	0.003	0.005	0.003	0.004
2C5-1	-	0.001,0.002	0.002	0.001	0.002	0.001	0.001
2C5-2	-	<0.001	0.002	0.001	0.002	0.001	0.001
2C5-4	-	-	0.002	0.002	0.002	0.001	0.001
2L1-1	-	-	-	-	-	0.93	0.75
2L1-2	-	-	-	-	-	0.52	0.39
2L1-3	-	-	-	-	-	0.37	0.43
2L1-4	-	-	-	-	-	-	0.32
2L1-5	-	-	-	-	-	-	0.32
2L1-6	-	-	-	-	-	-	0.30
2L2-1	-	-	-	-	-	0.003	0.002,0.002
2T1-1	0.001	0.002	0.001	0.038	0.042	0.075	#
2T1-2	-	-	-	0.004	0.008	0.012	#
2T1-3	-	-	-	0.005	0.019	0.018	#
2T1-4	-	-	-	-	0.006	0.010	#
2T1-5	-	-	-	-	0.011	0.027	#
2T2-1	0.002	0.001	0.001	0.020	0.058	0.134	#
2T2-2	-	-	-	0.003	0.008	0.022	#
2T2-3	-	-	-	0.015	0.038	0.115	#
2T2-4	-	-	-	0.006	0.018	0.058	#
2T2-5	-	-	-	0.005	0.013	0.044	#

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

- = measurement point not established.
= measurement not possible.

TABLE B-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
NATIVE BEES STUDIES

SITE NO., MEAS.PT.	1986 NS 4 amps	1986 NEW 6 amps	1986 SEW 6 amps	1986 SEW 10 amps (EX)	1987 NS 15 amps	1987 EW 15 amps	1988 NS 75 amps	1988 EW 75 amps	1989 B 150 amps
2C4-1	<	<	<	*	<	<	<	<	<
2C4-2	<	<	<	*	<	<	<	<	<
2C5-1	<	<	<	*	<	<	<	<	<
2C5-2	<	<	<	*	<	<	<	<	<
2C5-4	<	<	<	*	<	<	<	<	<
2L1-1	-	-	-	-	-	-	<	<	<,#
2L1-2	-	-	-	-	-	-	<	<	<,#
2L1-3	-	-	-	-	-	-	<	<	<,#
2L1-4	-	-	-	-	-	-	-	-	<,#
2L1-5	-	-	-	-	-	-	-	-	<,#
2L1-6	-	-	-	-	-	-	-	-	<,#
2L2-1	-	-	-	-	-	-	<	<	<
2T1-1	0.59	<	<	*	2.9	0.003	15.8	0.056	23
2T1-2	0.009	<	<	*	0.022	<	0.135	<0.001	0.23
2T1-3	0.005	<	<	*	0.019	<	0.095	0.001	0.178
2T1-4	-	-	-	-	0.007	<	0.027	0.001	0.054
2T1-5	-	-	-	-	/	/	0.39	0.002	0.63
2T2-1	0.182	<	<	*	0.48	<0.001	2.4	0.010	4.9
2T2-2	0.005	<	<	*	0.015	<0.001	0.079	0.001	0.142
2T2-3	0.123	<	<	*	0.42	<0.001	2.7	0.002	4.9
2T2-4	0.021	<	<	*	0.061	<0.001	0.38	0.002	0.54
2T2-5	0.012	<	<	*	0.039	<0.001	0.159	<0.001	0.29

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

- = measurement point not established.
/ = measurement not taken.
= measurement not possible.
< = est. <0.001 V/m based on E-field in ground.
* = data cannot be extrapolated.

TABLE B-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
NATIVE BEES STUDIES

	1986				1987		1988		1989
SITE NO., MEAS.PT.	NS 4 amps	NEW 6 amps	SEW 6 amps	SEW 10 amps (EX)	NS 15 amps	EW 15 amps	NS 75 amps	EW 75 amps	B 150 amps
2C4-1	/	/	/	*	0.006	0.003	0.027	0.017	0.072
2C4-2	0.002	0.001	0.001	0.002	0.006	0.004	0.030	0.022	0.105
2C5-1	0.008	0.004	0.006	0.010	0.022	0.018	0.112	0.110	0.36
2C5-2	/	/	/	*	0.008	0.008	0.041	0.042	0.179
2C5-4	/	/	/	*	0.001	0.005	0.020	0.027	0.114
2L1-1	-	-	-	-	-	-	#	#	#
2L1-2	-	-	-	-	-	-	#	#	#
2L1-3	-	-	-	-	-	-	#	#	#
2L1-4	-	-	-	-	-	-	-	-	#
2L1-5	-	-	-	-	-	-	-	-	#
2L1-6	-	-	-	-	-	-	-	-	#
2L2-1	-	-	-	-	-	-	0.006	0.002	0.013
2T1-1	1.97	0.064	0.108	0.180	8.2	0.23	24	0.77	70
2T1-2	1.08	0.037	0.070	0.117	3.3	0.21	13.1	0.98	32
2T1-3	1.31	0.051	0.101	0.168	5.2	0.33	23	1.40	45
2T1-4	-	-	-	-	4.5	0.191	30	1.38	59
2T1-5	-	-	-	-	/	/	22	0.96	36
2T2-1	5.4	0.159	0.086	0.143	32.	0.25	102	1.03	169
2T2-2	1.63	0.054	0.067	0.112	6.0	0.178	87	1.41	120
2T2-3	3.0	0.087	0.063	0.105	13.5	0.21	56	0.76	147
2T2-4	1.93	0.053	0.071	0.118	10.4	0.25	43	1.04	95
2T2-5	3.6	0.101	0.096	0.160	14.0	0.24	75	1.05	188

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

- = measurement point not established.
/ = measurement not taken.
= measurement not possible.
* = data cannot be extrapolated.

TABLE B-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
NATIVE BEES STUDIES

SITE NO., MEAS.PT.	1986 NS 4 amps	1986 NEW 6 amps	1986 SEW 6 amps	1986 SEW 10 amps (EX)	1987 NS 15 amps	1987 EW 15 amps	1988 NS 75 amps	1988 EW 75 amps	1989 B 150 amps
2C4-1	/	/	/	*	0.001	<0.001	0.002	0.001	0.006
2C4-2	<0.001	<0.001	<0.001	*	0.001	<0.001	0.003	0.001	0.006
2C5-1	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	0.001	0.002
2C5-2	/	/	/	*	<0.001	<0.001	0.001	0.001	0.002
2C5-4	/	/	/	*	<0.001	<0.001	0.001	0.001	0.003
2L1-1	-	-	-	-	-	-	/	/	#
2L1-2	-	-	-	-	-	-	/	/	#
2L1-3	-	-	-	-	-	-	/	/	#
2L1-4	-	-	-	-	-	-	-	-	#
2L1-5	-	-	-	-	-	-	-	-	#
2L1-6	-	-	-	-	-	-	-	-	#
2L2-1	-	-	-	-	-	-	<0.001	<0.001	0.002
2T1-1	0.77	0.024	0.004	0.007	3.1	0.004	14.4	0.052	31
2T1-2	0.125	0.004	<0.001	*	0.46	0.002	2.1	0.007	4.5
2T1-3	0.131	0.004	0.001	0.002	0.53	0.001	2.5	0.014	5.1
2T1-4	-	-	-	-	0.33	0.002	1.47	0.006	3.0
2T1-5	-	-	-	-	/	/	3.2	0.016	6.6
2T2-1	0.40	0.013	0.002	0.003	1.51	0.004	7.2	0.021	14.7
2T2-2	0.060	0.002	<0.001	*	0.22	0.002	1.05	0.005	2.1
2T2-3	0.35	0.011	0.002	0.003	1.33	0.002	6.2	0.026	12.8
2T2-4	0.158	0.005	0.001	0.002	0.58	0.001	2.9	0.015	5.5
2T2-5	0.124	0.004	0.001	0.002	0.46	0.001	2.2	0.013	4.4

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

\- = measurement point not established.
/ = measurement not taken.
= measurement not possible.
* = data cannot be extrapolated.

APPENDIX C

SOIL ARTHROPODS AND EARTHWORMS STUDIES

SOIL ARTHROPODS AND EARTHWORMS STUDIES

During September 1989, IITRI field crews made ELF electromagnetic (EM) field measurements at a total of eight measurement points at one treatment and one control site for the soil arthropods and earthworms studies. The study sites and the measurement points within those sites were unchanged from 1988.

The positions of the two sites relative to the NRTF-Republic are shown on the composite map in Figure C-1. The site numbers listed on the map are those used by IITRI. Table C-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are shown in Figures C-2 and C-3.

TABLE C-1. SITE NO. CROSS-REFERENCE
Soil Arthropods and Earthworms Studies

IITRI Site No.	Investigator's Site Name	Location		
		Township	Range	Section(s)
3T2	South Silver Lake	T44N	R29W	25
3C5	Turner Road	T43N	R30W	11

The soil arthropods and earthworms studies monitor species composition, population age structure, and distribution. The electric and magnetic fields in the earth are considered the most important EM factors influencing soil biota. The electric field in the air is not expected to have a significant impact on the objectives of these studies.

EM field measurements for 1989 and previous years are found in Tables C-2 through C-7. Tables C-2, C-3, and C-4 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables C-5, C-6, and C-7 present 76 Hz data for these fields at the corresponding operating currents of the NRTF-Republic.

The 60 Hz EM fields measured at the study sites in 1989 are consistent with those measured in previous years.

The 1989, 76 Hz measurements were made with 150 ampere antenna currents, the predominant operating current of the NRTF-Republic since 4 May 1989. The EM exposures at the study sites for the period prior to 4 May can be estimated either by using the 75 ampere antenna current measurement data from 1988 or by using one-half the value of the 1989, 150 ampere data.

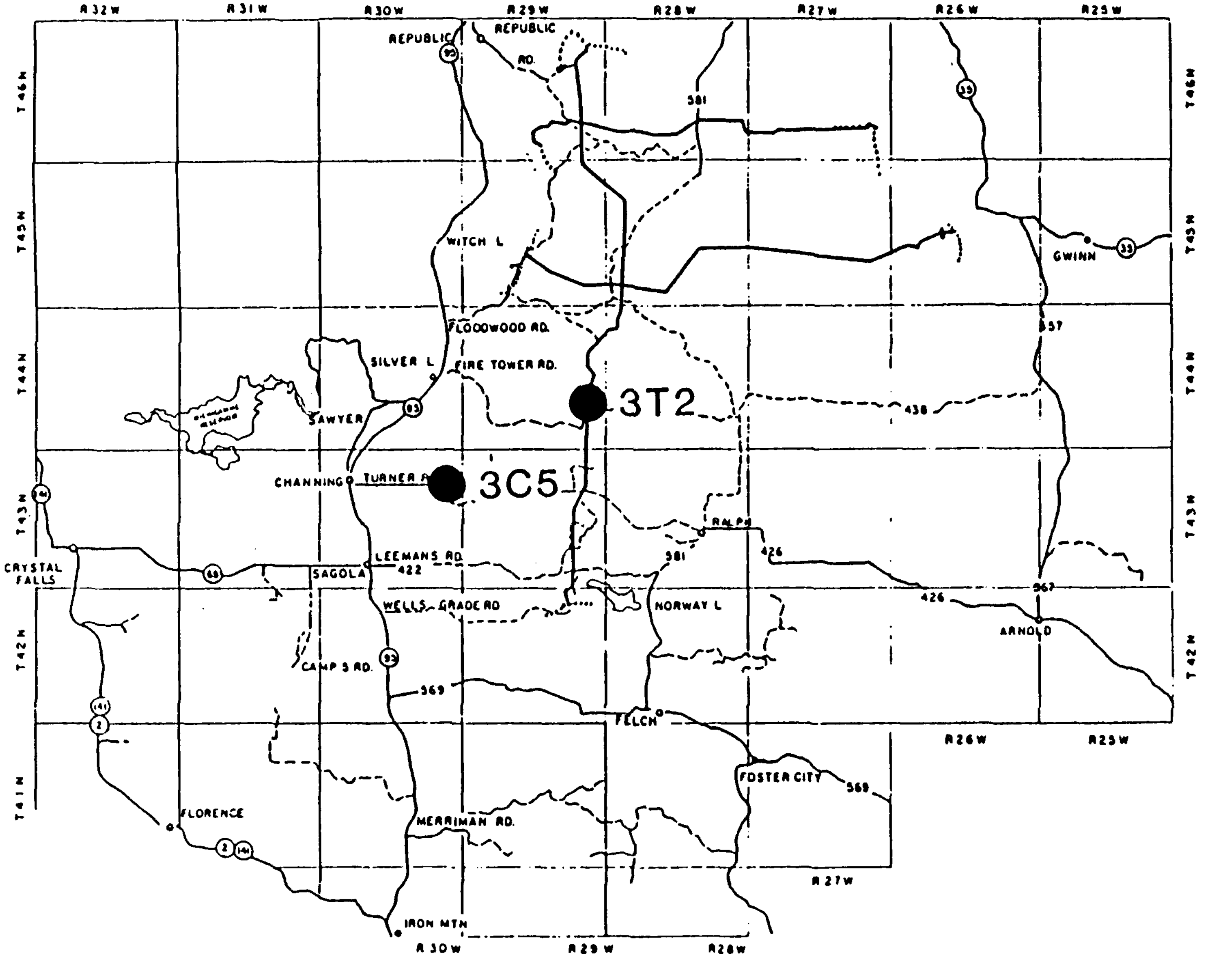


FIGURE C-1. POSITIONS OF SOIL ARTHROPODS AND EARTHWORMS STUDY SITES RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

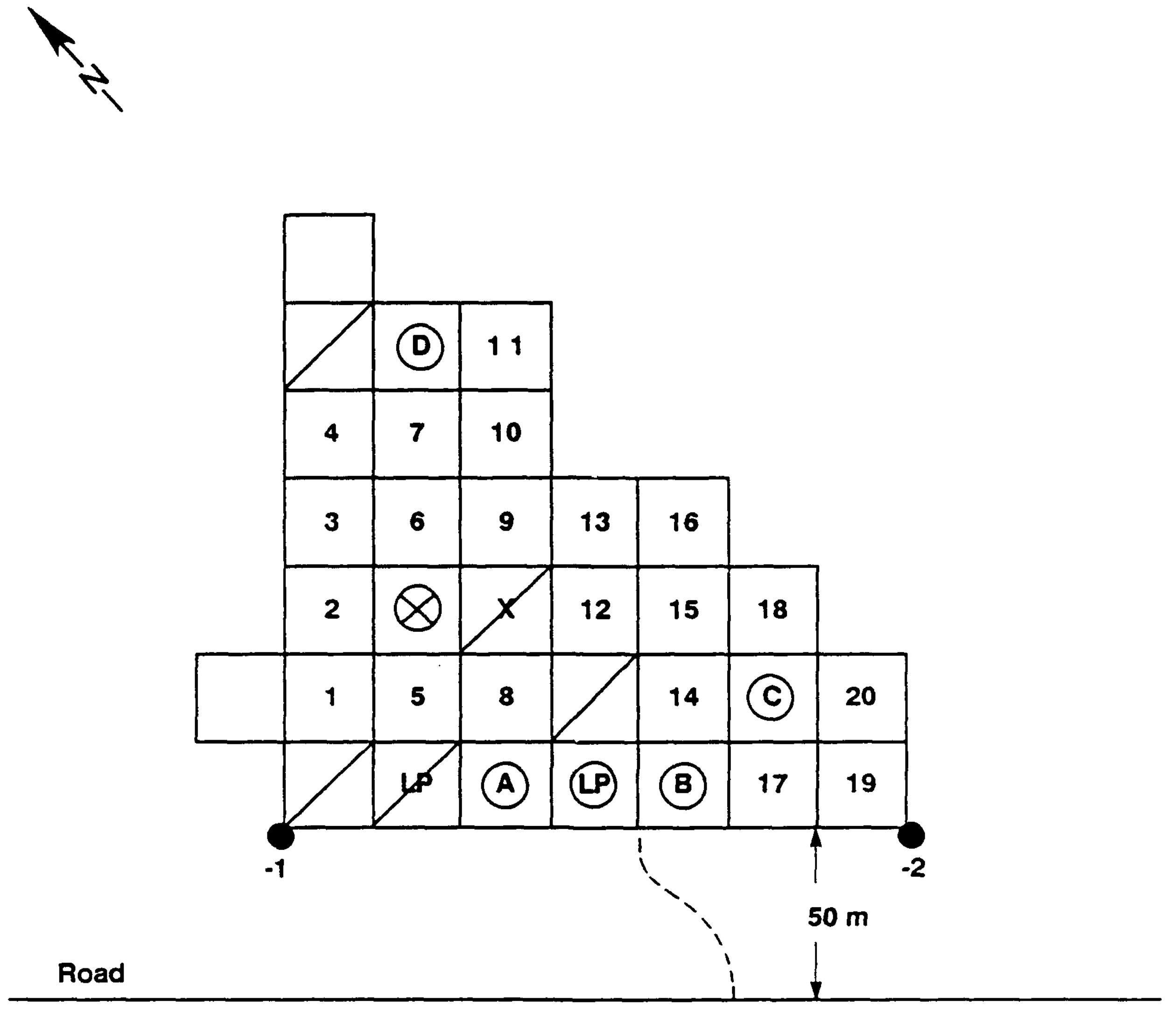


FIGURE C-2. MEASUREMENT POINTS AT TURNER ROAD; 3C5-1, 2.

60297/790

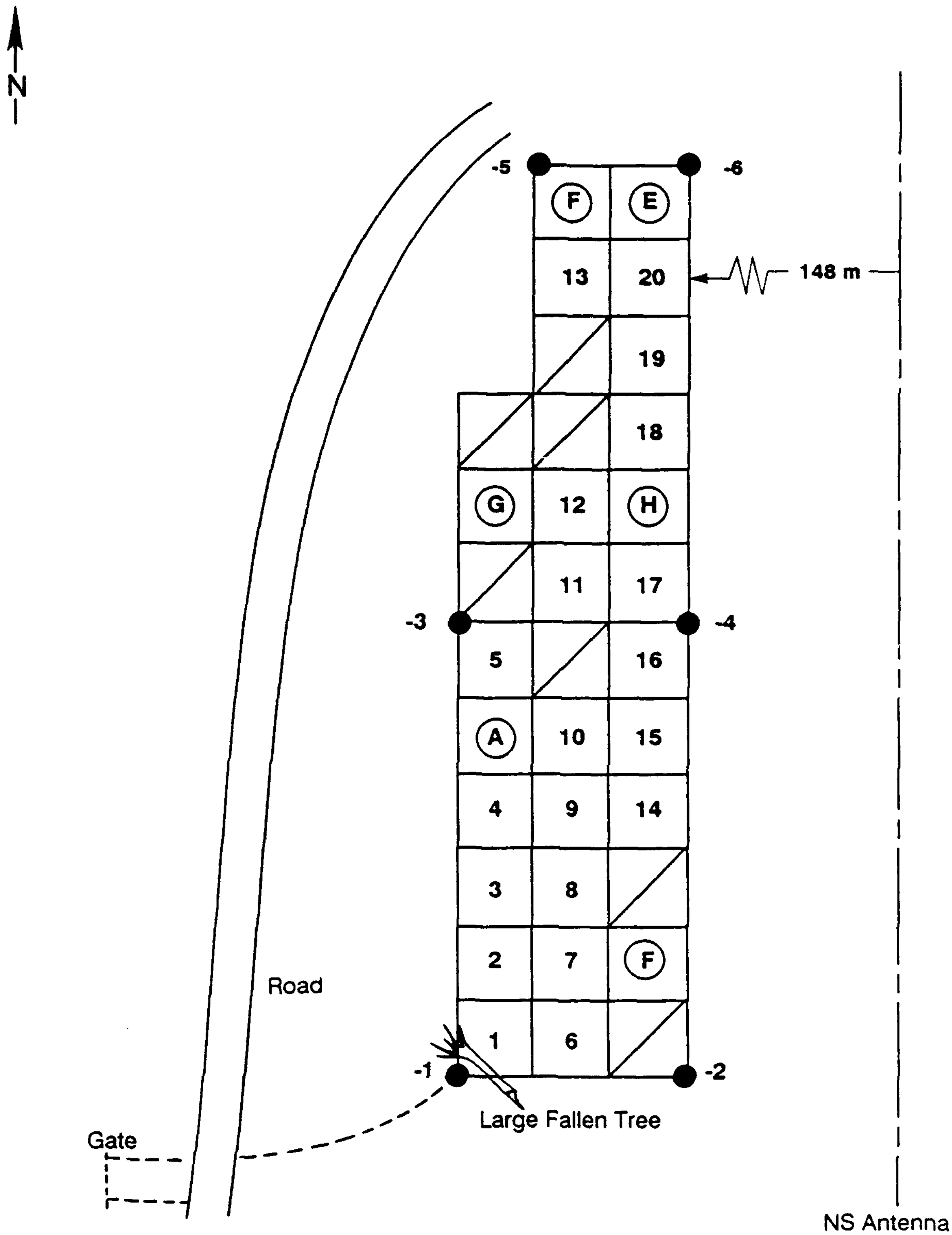


FIGURE C-3. MEASUREMENT POINTS AT SOUTH SILVER LAKE; 3T2-1 THROUGH 6.

60297/790

TABLE C-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	1983 [a]	1984 [a]	1985 [a]	1986 [b]	1987 [c]	1988 [c]	1989 [d]
3C5-1	<0.001	<0.001	<	<	<	<	<
3C5-2	-	-	-	<	<	<	<
3T2-1	<0.001	<0.001	<	<	<	<	<0.001
3T2-2	-	-	-	<	<	<	<
3T2-3	-	-	-	<	<	<	<
3T2-4	-	-	-	<	<	<	<
3T2-5	-	-	-	<	<	<	<
3T2-6	-	-	-	<	<	<	<

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

\- = measurement point not established.
< = est. <0.001 V/m based on E-field in ground.

TABLE C-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITES (mV/m)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]
3C5-1	0.063	0.018.0.032	0.036	0.027	0.054	0.054	0.062
3C5-2	-	-	-	0.027	0.071	0.085	0.182
3T2-1	0.106	0.129,0.27	0.194	0.045	0.042	0.091	0.055
3T2-2	-	-	-	0.068	0.049	0.093	0.049
3T2-3	-	-	-	0.038	0.043	0.084	0.035
3T2-4	-	-	-	0.045	0.039	0.087	0.068
3T2-5	-	-	-	0.044	0.045	0.084	0.053
3T2-6	-	-	-	0.048	0.033	0.087	0.041

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

- = measurement point not established.

TABLE C-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	1983 [a]	1984 [a]	1985 [a]	1986 [b]	1987 [c]	1988 [c]	1989 [d]
3C5-1	0.001	0.001	0.001	0.001	0.002	0.001	0.001
3C5-2	-	-	-	<0.001	0.001	0.001	0.002
3T2-1	<0.001	<0.001	0.001	0.005	0.002	0.004	0.001
3T2-2	-	-	-	0.006	0.003	0.006	0.002
3T2-3	-	-	-	0.004	0.003	0.003	0.001
3T2-4	-	-	-	0.005	0.003	0.005	0.002
3T2-5	-	-	-	0.005	0.003	0.004	0.002
3T2-6	-	-	-	0.004	0.003	0.003	0.001

a = prior to antenna construction.
b = antennas *grounded* at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

- = measurement point not established.

TABLE C-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Soil Arthropods and Earthworms Studies

SITE NO., MEAS. PT.	1986 NS 4 amps	1986 NEW 6 amps	1986 SEW 6 amps	1986 SEW 10 amps (EX)	1987 NS 15 amps	1987 EW 15 amps	1988 NS 75 amps	1988 EW 75 amps	1989 B 150 amps
3C5-1	<	<	<	*	<	<	<	<	<
3C5-2	<	<	<	*	<	<	<	<	<
3T2-1	0.002	<	<	*	0.006	<	0.031	0.003	0.064
3T2-2	0.002	<	<	*	0.006	<	0.024	0.003	0.070
3T2-3	0.002	<	<	*	0.006	<	0.028	0.003	0.048
3T2-4	0.002	<	<	*	0.006	<	0.026	0.003	0.055
3T2-5	0.002	<	<	*	0.006	<	0.029	0.005	0.061
3T2-6	0.002	<	<	*	0.006	<	0.027	0.002	0.048

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = *NS + EW antennas, standard phasing.*
EX = extrapolated data.

< = est. *<0.001 V/m based on E-field in ground.*
* = data cannot be extrapolated.

TABLE C-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Soil Arthropods and Earthworms Studies

SITE NO., MEAS. PT.	1986 NS 4 amps	1986 NEW 6 amps	1986 SEW 6 amps	1986 SEW 10 amps (EX)	1987 NS 15 amps	1987 EW 15 amps	1988 NS 75 amps	1988 EW 75 amps	1989 B 150 amps
3C5-1	0.005	0.001	0.002	0.003	0.020	0.006	0.093	0.027	0.22
3C5-2	0.009	0.001	0.003	0.005	0.034	0.009	0.170	0.021	0.38
3T2-1	1.33	0.057	0.188	0.31	5.4	0.54	27	2.6	58
3T2-2	1.46	0.064	0.24	0.40	6.3	0.71	26	3.0	60
3T2-3	1.19	0.047	0.149	0.25	5.3	0.60	27	2.7	49
3T2-4	1.47	0.060	0.20	0.33	5.6	0.47	29	2.6	62
3T2-5	1.56	0.070	0.23	0.38	5.7	0.61	27	2.8	52
3T2-6	1.20	0.056	0.180	0.30	5.5	0.54	27	2.4	49

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW *antennas, standard phasing.*
EX = extrapolated data.

TABLE C-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Arthropods and Earthworms Studies

SITE NO., MEAS.PT.	1986				1987		1988		1989
	NS 4 amps	NEW 6 amps	SEW 6 amps	SEW 10 amps (EX)	NS 15 amps	EW 15 amps	NS 75 amps	EW 75 amps	B 150 amps
3C5-1	<0.001	<0.001	<0.001	*	0.002	0.001	0.008	0.003	0.019
3C5-2	<0.001	<0.001	<0.001	*	0.002	0.001	0.007	0.002	0.017
3T2-1	0.048	0.001	0.001	0.002	0.187	0.003	0.88	0.012	1.84
3T2-2	0.060	0.002	0.001	0.002	0.23	0.003	1.11	0.012	2.3
3T2-3	0.046	0.001	0.001	0.002	0.182	0.002	0.89	0.012	1.81
3T2-4	0.055	0.002	0.001	0.002	0.23	0.003	1.08	0.012	2.3
3T2-5	0.057	0.002	0.001	0.002	0.22	0.003	1.03	0.012	2.2
3T2-6	0.049	0.001	0.001	0.002	0.190	0.003	0.90	0.012	1.88

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

* = data cannot be extrapolated.

APPENDIX D

UPLAND FLORA AND SOIL MICROFLORA STUDIES

UPLAND FLORA AND SOIL MICROFLORA STUDIES

During September and October, 1989, IITRI field crews made ELF electromagnetic (EM) field measurements at 45 measurement points at two treatment sites, one control site, and three leaf sample collection points. The measurement points differed from those used in 1988 in that five new points (4T2-15 through 19) were added and two previously abandoned points (4T2-8, 4T2-12) were reactivated at the antenna site, and eight new points (4T4-13 through 20) were added at the ground site, in 1989. These measurement points were added at the antenna and ground treatment sites in order to characterize the EM field gradients across the sites more precisely.

The positions of the study sites relative to the NRTF-Republic are shown on the composite map in Figure D-1. The site numbers listed on the map are those used by IITRI. Table D-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are shown in Figures D-2 through D-6.

TABLE D-1. SITE NO. CROSS-REFERENCE
Upland Flora and Soil Microflora Studies

IITRI Site No.	Investigator's Site Name	Location Township	: Range	: Section(s)
4T2	Martell's Lake (Overhead): ML	T45N	: R29W	: 28
4T4	Martell's Lake (Buried): EP	T45N	: R29W	: 28
4C1	Paint Pond Road Control	T41N	: R32W	: 3
4S1	Red Maple Leaf Collection	T55N	: R35W	: 21
4S2	Oak Leaf Collection	T41N	: R32W	: 3
4S3	Pine Needle Collection	T54N	: R34W	: 5

The treatment sites straddle the antenna and grounding elements of the NRTF-Republic; the control site is located more than 28 miles from the nearest antenna element. The antenna treatment site and the control site are arranged in a similar manner, each consisting of three overstory tree plots (pole stands), three plots cleared and planted with red pine seedlings (plantations), and three plots set aside for the study of herbaceous plants (reserves). The ground treatment site consists of only three plots cleared and planted with red pine. No overstory tree plots or herbaceous reserves were established at the ground treatment site, because the required buffer strips would have resulted in the biota being at too great a distance from the grounding elements for meaningful EM field exposure.

The major themes of the upland flora and microflora studies are the functional and structural aspects of organic material cycling. These studies investigate and characterize trees, herbaceous plants, and microflora (fungi and streptomycetes) populations. The electric and magnetic fields in the earth are considered important EM factors influencing soil biota and processes. The electric and magnetic fields in the air may influence any object extending above the surface of the earth. Since the electric field in the air can be effectively shunted by trees or plants on the perimeter of a given study plot, special care was taken in characterizing the ambient electric field intensities across a plot.

EM field measurements for 1989 and previous years are found in Tables D-2 through D-7. Tables D-2, D-3, and D-4 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables D-5, D-6, and D-7 present 76 Hz data for these fields at the corresponding operating current of the NRTF-Republic for each year. 76 Hz measurements were made at all points and gradient plots; a discussion of these measurements appears in Section 4.3.1 of this report.

Ambient 60 Hz EM field intensities could not be measured at the treatment sites in 1989 because of modulated signal operation of the NRTF-Republic during measurements at these sites. The 60 Hz EM field intensities measured at the control and leaf collection sites are consistent with values measured in previous years.

The 1989, 76 Hz measurements were made with 150 ampere antenna currents, the predominant operating current of the NRTF-Republic since 4 May 1989. The EM exposures at the study sites for the period prior to 4 May can be estimated either by using the 75 ampere current measurement data from 1988 or by using one-half the value of the 1989, 150 ampere data.

60297/190

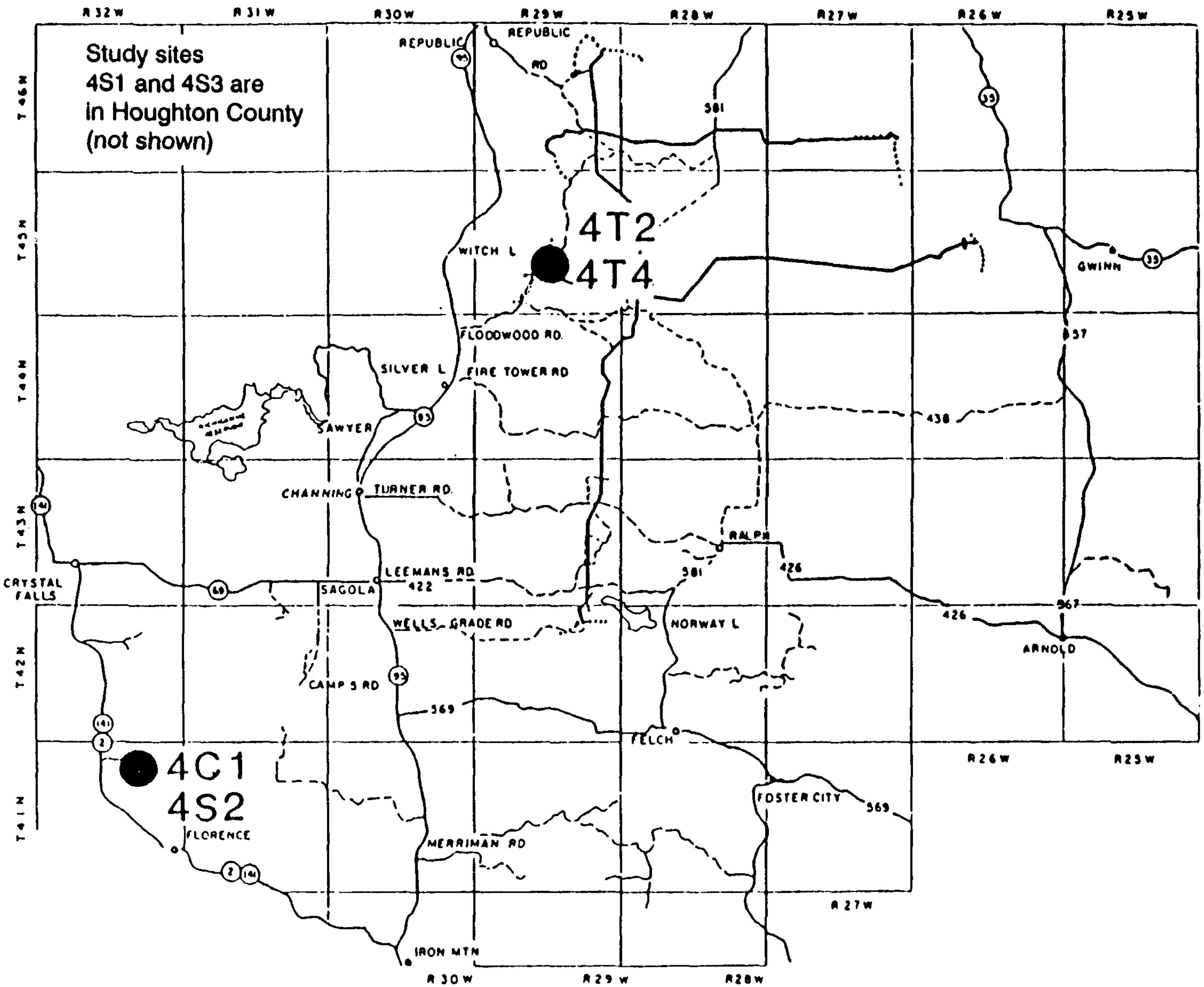


FIGURE D-1. POSITIONS OF UPLAND FLORA AND SOIL MICROFLORA STUDY SITES RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

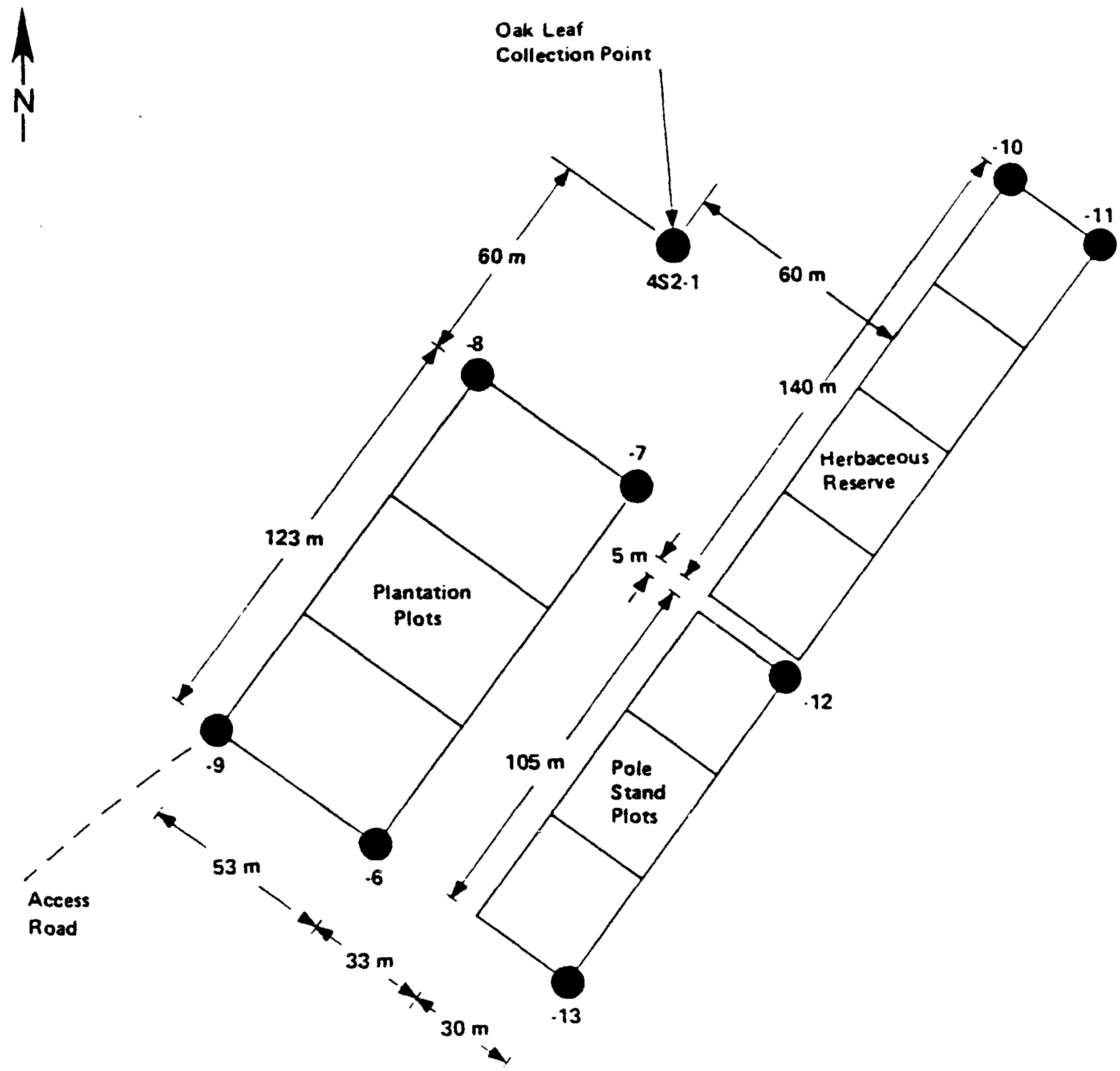


FIGURE D-2. MEASUREMENT POINTS AT PAINT POND ROAD CONTROL; 4C1-6 THROUGH 13, AND OAK LEAF COLLECTION SITE; 4S2-1.

60297/790

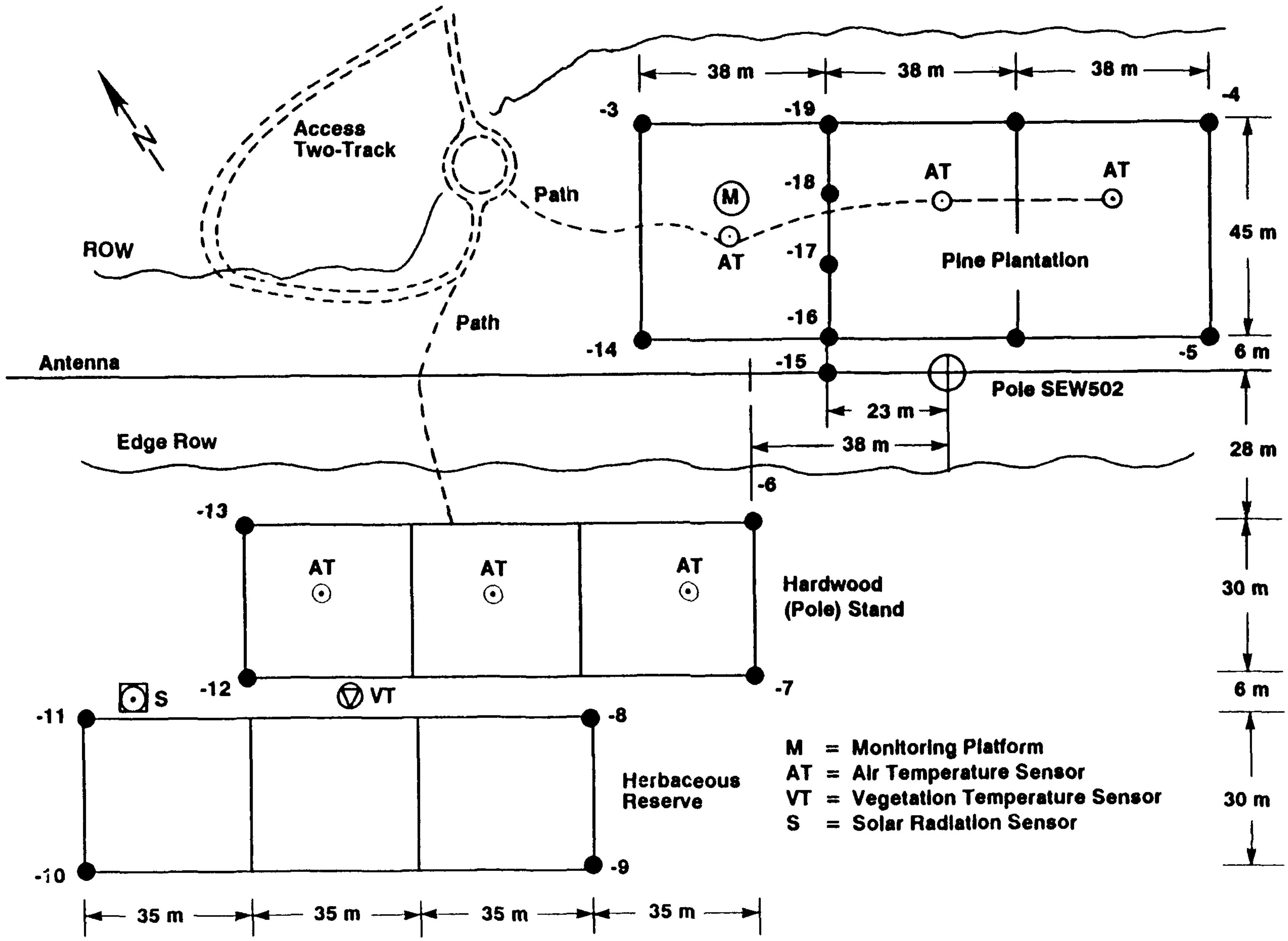


FIGURE D-3. MARTELL'S LAKE (OVERHEAD): ML; 4T2-3 THROUGH 19.

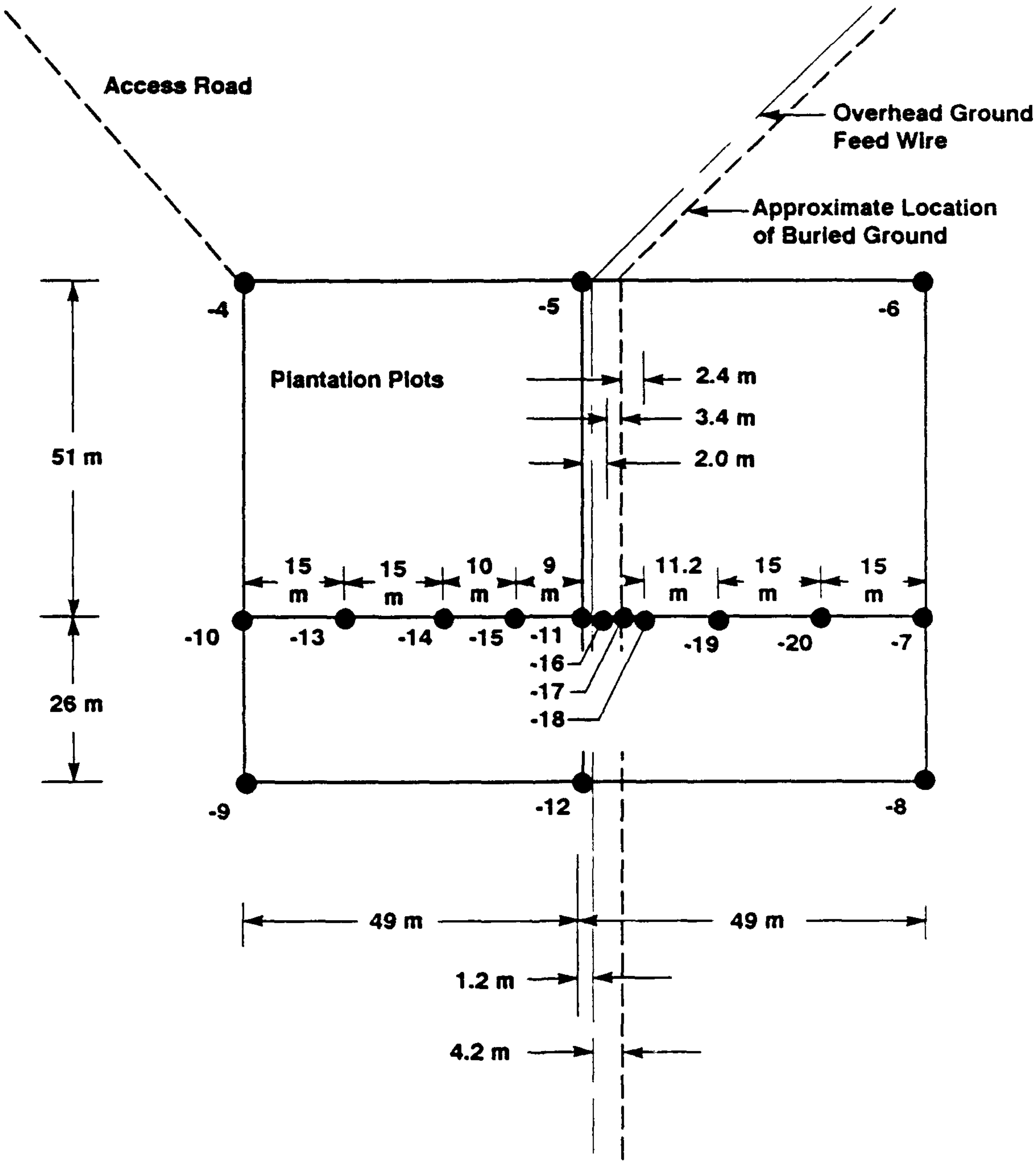


FIGURE D-4. MARTELL'S LAKE (BURIED): EP; 4T4-4 THROUGH 20.

60297/790

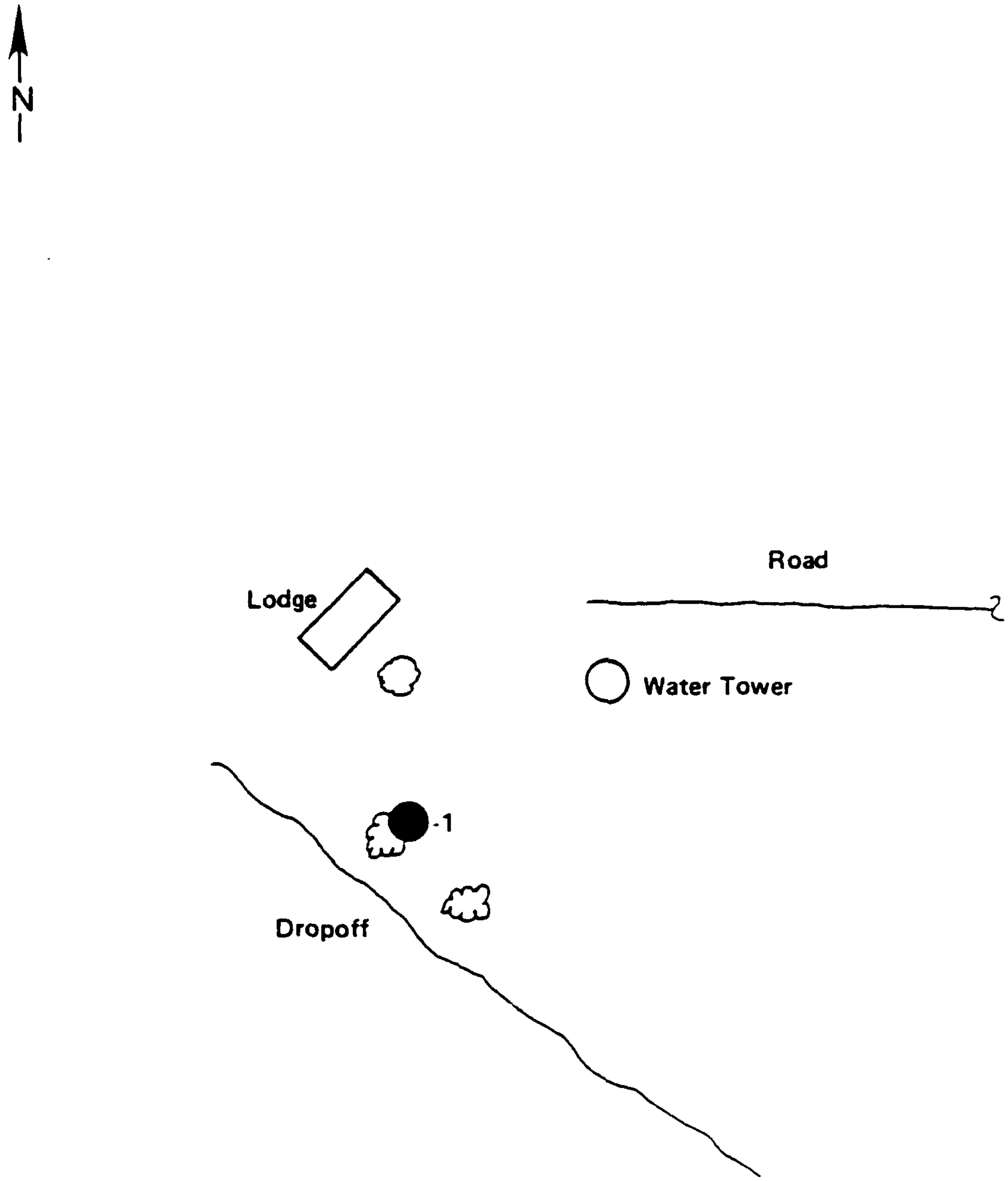


FIGURE D-5. MEASUREMENT POINT AT RED MAPLE LEAF SAMPLE COLLECTION SITE; 4 S1-1.

60297/790

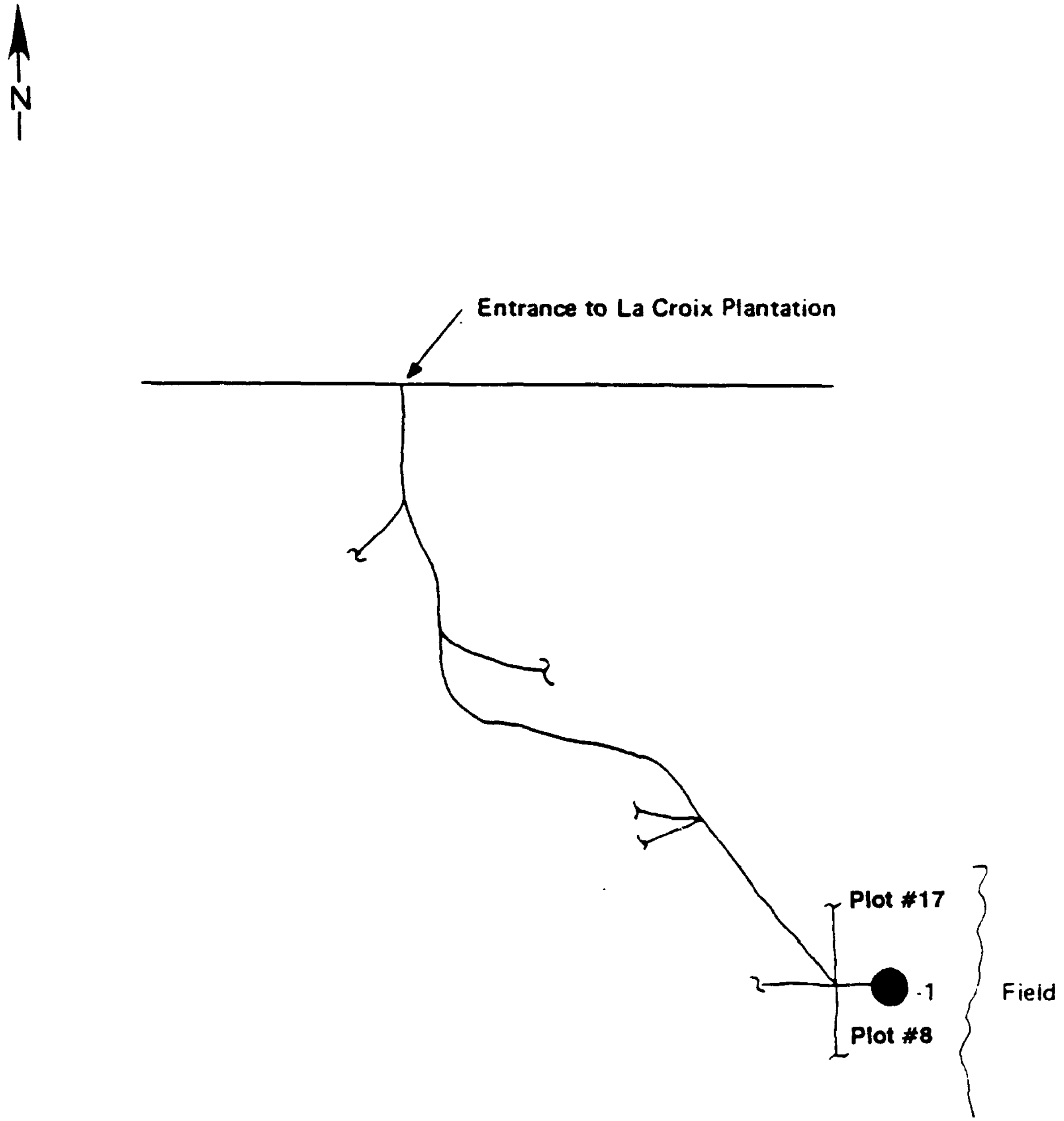


FIGURE D-6. MEASUREMENT POINT AT THE PINE NEEDLE SAMPLE COLLECTION SITE; 4S3-1.

TABLE D-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies
(page 1 of 2)

Site No., Meas. Pt.	a 1983	a 1984	a 1985	b 1986	c 1987	c 1988	d 1989
4C1-6	-	0.003	<	<	<	<	<
4C1-7	-	0.006	<	<	<	<	<
4C1-8	-	0.004	<	<	<	<	<
4C1-9	-	0.002	<	<	<	<	<
4C1-10	-	-	<	<	<	<	<
4C1-11	-	-	<	<	<	<	<
4C1-12	-	-	<	<	<	<	<
4C1-13	-	-	<	<	<	<	<
4T2-3	-	0.001	<	<	<	0.002	#
4T2-4	-	-	<	<	<	0.001	#
4T2-5	-	-	<	<	<	0.011	#
4T2-6	-	-	<	<	<	<0.001	#
4T2-7	-	-	<	<	<	<0.001	#
4T2-8	-	-	<	<	<	/	#
4T2-9	-	-	<	<	<	<	#
4T2-10	-	-	<	<	<	<	#
4T2-11	-	-	<	<	<	<	#
4T2-12	-	-	<	<	<	/	#
4T2-13	-	-	<	<	<	<0.001	#
4T2-14	-	-	<	<	<	0.011	#
4T2-15	-	-	-	-	-	-	#
4T2-16	-	-	-	-	-	-	#
4T2-17	-	-	-	-	-	-	#
4T2-18	-	-	-	-	-	-	#
4T2-19	-	-	-	-	-	-	#

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

\- = measurement point not established.
/ = measurement not taken.
\# = measurement not possible.
< = est. <0.001 V/m based on E-field in ground.

TABLE D-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

Site No., Meas. Pt.	a 1983	a 1984	a 1985	b 1986	c 1987	c 1988	d 1989
4T4-4	-	0.003	<	<	<0.001	<0.001	#
4T4-5	-	-	<	<	0.006	0.003	#
4T4-6	-	-	<	<	<	<	#
4T4-7	-	-	<	<	<	<	#
4T4-8	-	-	<	<	<	<	#
4T4-9	-	-	<	<	<	<	#
4T4-10	-	-	<	<	<	<	#
4T4-11	-	-	<	<	0.010	0.009	#
4T4-12	-	-	-	<	0.005	0.007	#
4T4-13	-	-	-	-	-	-	#
4T4-14	-	-	-	-	-	-	#
4T4-15	-	-	-	-	-	-	#
4T4-16	-	-	-	-	-	-	#
4T4-17	-	-	-	-	-	-	#
4T4-18	-	-	-	-	-	-	#
4T4-19	-	-	-	-	-	-	#
4T4-20	-	-	-	-	-	-	#
4S1-1	-	-	-	-	0.013	0.033	0.011
4S2-1	-	-	-	-	<	<	<
4S3-1	-	-	-	-	<0.001	<0.001	<0.001

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

\- = measurement point not established.
/ = measurement not taken.
\# = measurement not possible.
< = est. <0.001 V/m based on E-field in ground.

TABLE D-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITES (mV/m)
Upland Flora and Soil Microflora Studies
(page 1 of 2)

Site No., Meas. Pt.	1983 [a]	1984 [a]	1985 [a]	1986 [b]	1987 [c]	1988 [c]	1989 [d]
4C1-6	-	0.022	0.016	0.005	0.043	0.023	0.016
4C1-7	-	0.143	0.123	0.077	0.178	0.118	0.030
4C1-8	-	0.104	0.117	0.077	0.131	0.078	0.018
4C1-9	-	0.011	0.019	0.024	0.034	0.032	0.023
4C1-10	-	-	0.090	0.068	0.118	0.106	0.054
4C1-11	-	-	0.160	0.107	0.132	0.146	0.066
4C1-12	-	-	0.104	0.101	0.075	0.093	0.042
4C1-13	-	-	0.040	0.030	0.046	0.065	0.025
4T2-3	-	0.51	0.39	0.194	0.27	0.28	#
4T2-4	-	-	0.27	0.24	0.30	0.25	#
4T2-5	-	-	0.43	0.32	0.20	0.20	#
4T2-6	-	-	0.66	0.46	0.192	0.22	#
4T2-7	-	-	0.42	0.52	0.197	0.28	#
4T2-8	-	-	0.47	0.190	0.22	/	#
4T2-9	-	-	0.49	0.31	0.183	0.25	#
4T2-10	-	-	0.44	0.32	0.155	0.166	#
4T2-11	-	-	0.51	0.40	0.31	0.43	#
4T2-12	-	-	0.47	0.38	0.24	/	#
4T2-13	-	-	0.76	0.31	0.31	0.25	#
4T2-14	-	-	0.61	0.29	0.35	0.21	#
4T2-15	-	-	-	-	-	-	#
4T2-16	-	-	-	-	-	-	#
4T2-17	-	-	-	-	-	-	#
4T2-18	-	-	-	-	-	-	#
4T2-19	-	-	-	-	-	-	#

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

\- = measurement point not established.
/ = measurement not taken.
= measurement not possible.

TABLE D-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITES (mV/m)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

Site No., Meas. Pt.	1983 a	1984 a	1985 a	1986 b	1987 c	1988 c	1989 d
4T4-4	-	0.72	0.42	0.185	0.56	0.079	#
4T4-5	-	-	0.58	0.58	4.3	1.12	#
4T4-6	-	-	0.22	0.16	0.61	0.188	#
4T4-7	-	-	0.44	0.29	0.64	0.22	#
4T4-8	-	-	0.42	0.193	0.40	0.23	#
4T4-9	-	-	0.50	0.21	0.27	0.073	#
4T4-10	-	-	0.42	0.22	0.29	0.063	#
4T4-11	-	-	0.40	0.60	2.7	1.27	#
4T4-12	-	-	-	0.75	3.4	1.35	#
4T4-13	-	-	-	-	-	-	#
4T4-14	-	-	-	-	-	-	#
4T4-15	-	-	-	-	-	-	#
4T4-16	-	-	-	-	-	-	#
4T4-17	-	-	-	-	-	-	#
4T4-18	-	-	-	-	-	-	#
4T4-19	-	-	-	-	-	-	#
4T4-20	-	-	-	-	-	-	#
4S1-1	-	-	-	-	8.5	12.2	11.6
4S2-1	-	-	-	-	0.155	0.109	0.032
4S3-1	-	-	-	-	0.65	1.73	0.73

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

\- = measurement point not established.
/ = measurement not taken.
= measurement not possible.

TABLE D-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies
(page 1 of 2)

Site No., Meas. Pt.	1983 [a]	1984 [a]	1985 [a]	1986 [b]	1987 [c]	1988 [c]	1989 [d]
4C1-6	-	0.003	0.003	0.003	0.002	0.003	0.002
4C1-7	-	0.003	0.002	0.001	0.003	0.002	0.001
4C1-8	-	0.003	0.003	0.002	0.003	0.002	0.001
4C1-9	-	0.003	0.003	0.002	0.001	0.002	0.002
4C1-10	-	-	0.002	0.002	0.002	0.002	0.002
4C1-11	-	-	0.002	0.002	0.002	0.002	0.001
4C1-12	-	-	0.002	0.003	0.001	0.002	0.001
4C1-13	-	-	0.002	0.003	0.001	0.003	0.002
4T2-3	-	0.002	0.001	0.001	0.003	0.005	#
4T2-4	-	-	0.001	0.001	0.003	0.006	#
4T2-5	-	-	0.001	0.007	0.017	0.030	#
4T2-6	-	-	0.001	0.006	0.006	0.014	#
4T2-7	-	-	0.001	0.004	0.004	0.007	#
4T2-8	-	-	0.001	0.002	0.004	/	#
4T2-9	-	-	0.001	0.003	0.003	0.005	#
4T2-10	-	-	0.001	0.003	0.003	0.005	#
4T2-11	-	-	0.001	0.004	0.005	0.007	#
4T2-12	-	-	0.002	0.004	0.005	/	#
4T2-13	-	-	0.001	0.005	0.008	0.013	#
4T2-14	-	-	0.002	0.011	0.018	0.029	#
4T2-15	-	-	-	-	-	-	#
4T2-16	-	-	-	-	-	-	#
4T2-17	-	-	-	-	-	-	#
4T2-18	-	-	-	-	-	-	#
4T2-19	-	-	-	-	-	-	#

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

\- = measurement point not established.
/ = measurement not taken.
= measurement not possible.

TABLE D-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

Site No., Meas. Pt.	1983 [a]	1984 [a]	1985 [a]	1986 [b]	1987 [c]	1988 [c]	1989 [d]
4T4-4	-	0.004	0.002	0.001	0.003	0.003	#
4T4-5	-	-	0.002	0.006	0.010	0.017	#
4T4-6	-	-	0.002	0.001	0.004	0.007	#
4T4-7	-	-	0.001	0.001	0.004	0.005	#
4T4-8	-	-	0.002	0.001	0.004	0.005	#
4T4-9	-	-	0.002	0.001	0.002	0.003	#
4T4-10	-	-	0.001	0.001	0.002	0.002	#
4T4-11	-	-	0.002	0.002	0.012	0.019	#
4T4-12	-	-	-	0.002	0.010	0.016	#
4T4-13	-	-	-	-	-	-	#
4T4-14	-	-	-	-	-	-	#
4T4-15	-	-	-	-	-	-	#
4T4-16	-	-	-	-	-	-	#
4T4-17	-	-	-	-	-	-	#
4T4-18	-	-	-	-	-	-	#
4T4-19	-	-	-	-	-	-	#
4T4-20	-	-	-	-	-	-	#
4S1-1	-	-	-	-	0.035	0.043	0.052
4S2-1	-	-	-	-	0.003	0.002	0.002
4S3-1	-	-	-	-	0.036	0.095	0.028

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

\- = measurement point not established.
/ = measurement not taken.
= measurement not possible.

TABLE D-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies
(page 1 of 2)

SITE NO., MEAS.PT.	1986 NS 4 amps	1986 NEW 6 amps	1986 SEW 6 amps	1986 SEW 10 amps (EX)	1987 NS 15 amps	1987 EW 15 amps	1988 NS 75 amps	1988 EW 75 amps	1989 B 150 amps
4C1-6	<	<	<	*	<	<	<	<	<
4C1-7	<	<	<	*	<	<	<	<	<
4C1-8	<	<	<	*	<	<	<	<	<
4C1-9	<	<	<	*	<	<	<	<	<
4C1-10	<	<	<	*	<	<	<	<	<
4C1-11	<	<	<	*	<	<	<	<	<
4C1-12	<	<	<	*	<	<	<	<	<
4C1-13	<	<	<	*	<	<	<	<	<
4T2-3	<	<	0.004	0.007	0.002	0.014	0.006	0.125	0.142
4T2-4	<	<	0.005	0.008	0.001	0.014	0.017	0.113	0.149
4T2-5	0.018	<	0.092	0.153	0.003	0.23	0.033	2.6	1.31
4T2-6	<	<	0.005	0.008	0.003	0.013	0.014	0.142	0.138
4T2-7	<	<	0.007	0.012	0.001	0.018	0.020	0.165	0.173
4T2-8	<	<	0.004	0.007	0.002	0.012	/	/	0.124
4T2-9	<	<	0.005	0.008	0.00?	0.010	0.019	0.137	0.12
4T2-10	<	<	0.004	0.007	0.002	0.011	0.020	0.112	0.113
4T2-11	<	<	0.003	0.005	0.002	0.012	0.010	0.130	0.22
4T2-12	<	<	0.002	0.003	0.002	0.014	/	/	0.095
4T2-13	<	<	0.005	0.008	0.002	0.012	0.010	0.121	0.125
4T2-14	0.030	<	0.155	0.26	0.003	0.186	0.026	2.5	1.66
4T2-15	-	-	-	-	-	-	-	-	2.3
4T2-16	-	-	-	-	-	-	-	-	1.92
4T2-17	-	-	-	-	-	-	-	-	0.69
4T2-18	-	-	-	-	-	-	-	-	0.28
4T2-19	-	-	-	-	-	-	-	-	0.107

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

- = measurement point not established.
/ = measurement not taken.
= measurement not possible.
* = data cannot be extrapolated.
< = est. <0.001 V/m based on E-field in ground.

TABLE D-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

SITE NO., MEAS.PT.	1986 NS 4 amps	1986 NEW 6 amps	1986 SEW 6 amps	1986 SEW 10 amps (EX)	1987 NS 15 amps	1987 EW 15 amps	1988 NS 75 amps	1988 EW 75 amps	1989 B 150 amps
4T4-4	<	<	0.006	0.010	0.002	0.005	0.008	0.028	0.067
4T4-5	0.033	0.008	0.20	0.33	0.019	0.27	0.089	1.31	4.8
4T4-6	0.005	<	0.023	0.038	0.002	0.021	0.011	0.064	0.175
4T4-7	<	<	0.006	0.010	0.002	0.015	0.008	0.090	0.133
4T4-8	<	<	0.008	0.013	0.002	0.016	0.007	0.083	0.145
4T4-9	<	<	0.009	0.015	0.001	0.008	0.009	0.047	0.095
4T4-10	<	<	0.007	0.012	0.001	0.001	0.011	0.057	0.112
4T4-11	<	0.005	0.38	0.63	0.025	0.43	0.20	4.4	5.0
4T4-12	0.055	0.005	0.43	0.72	0.017	0.30	0.150	2.1	4.5
4T4-13	-	-	-	-	-	-	-	-	0.26
4T4-14	-	-	-	-	-	-	-	-	0.88
4T4-15	-	-	-	-	-	-	-	-	2.7
4T4-16	-	-	-	-	-	-	-	-	5.9
4T4-17	-	-	-	-	-	-	-	-	4.5
4T4-18	-	-	-	-	-	-	-	-	4.8
4T4-19	-	-	-	-	-	-	-	-	1.16
4T4-20	-	-	-	-	-	-	-	-	0.32
4S1-1	-	-	-	-	<	<	<	<	#
4S2-1	-	-	-	-	<	<	<	<	<
4S3-1	-	-	-	-	<	<	<	<	#

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

- = measurement point not established.
/ = measurement not taken.
= measurement not possible.
* = data cannot be extrapolated.
< = est. <0.001 V/m based on E-field in ground.

TABLE D-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies
(page 1 of 2)

SITE NO., MEAS.PT.	1986 NS 4 amps	1986 NEW 6 amps	1986 SEW 6 amps	1986 SEW 10 amps (EX)	1987 NS 15 amps	1987 EW 15 amps	1988 NS 75 amps	1988 EW 75 amps	1989 B 150 amps
4C1-6	<0.001	<0.001	<0.001	*	0.002	0.002	0.007	0.005	0.030
4C1-7	<0.001	<0.001	<0.001	*	0.005	0.006	0.024	0.023	0.091
4C1-8	<0.001	<0.001	<0.001	*	0.004	0.004	0.017	0.016	0.076
4C1-9	<0.001	<0.001	<0.001	*	0.002	0.002	0.007	0.006	0.030
4C1-10	<0.001	<0.001	<0.001	*	0.005	0.004	0.026	0.023	0.087
4C1-11	<0.001	<0.001	<0.001	*	0.006	0.005	0.028	0.028	0.113
4C1-12	<0.001	<0.001	<0.001	*	0.004	0.003	0.016	0.016	0.068
4C1-13	<0.001	<0.001	<0.001	*	0.002	0.002	0.012	0.011	0.051
4T2-3	1.31	0.22	6.3	10.5	1.36	15.2	7.7	76	131
4T2-4	1.05	0.22	5.0	8.3	1.70	10.7	6.2	68	135
4T2-5	1.18	0.24	5.3	8.8	1.46	12.7	8.2	62	86
4T2-6	1.11	0.27	4.4	7.3	2.2	12.4	10.4	56	105
4T2-7	1.13	0.23	5.3	8.8	1.31	9.7	8.8	71	90
4T2-8	1.32	0.25	5.7	9.5	1.81	15.8	/	/	141
4T2-9	1.17	0.21	5.1	8.5	1.46	13.7	7.1	63	119
4T2-10	0.97	0.22	4.1	6.8	1.84	10.5	8.1	50	96
4T2-11	1.14	0.21	5.0	8.3	2.2	10.7	9.6	122	182
4T2-12	1.06	0.21	4.3	7.2	1.93	13.5	/	/	99
4T2-13	1.12	0.64	5.4	9.0	1.74	14.9	8.2	71	138
4T2-14	1.07	0.175	5.1	8.5	1.66	14.3	6.6	56	124
4T2-15	-	-	-	-	-	-	-	-	73
4T2-16	-	-	-	-	-	-	-	-	88
4T2-17	-	-	-	-	-	-	-	-	104
4T2-18	-	-	-	-	-	-	-	-	95
4T2-19	-	-	-	-	-	-	-	-	107

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

- = measurement point not established.
/ = measurement not taken.
= measurement not possible.
* = data cannot be extrapolated.

TABLE D-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

SITE NO., MEAS.PT.	1986 NS 4 amps	1986 NEW 6 amps	1986 SEW 6 amps	1986 SEW 10 amps (EX)	1987 NS 15 amps	1987 EW 15 amps	1988 NS 75 amps	1988 EW 75 amps	1989 B 150 amps
4T4-4	0.33	0.181	1.46	2.4	1.63	3.7	7.2	16.5	42
4T4-5	13.8	2.0	81.	135.	14.0	194.	68	910	2100
4T4-6	1.22	0.22	6.2	10.3	2.2	12.9	10.3	62	140
4T4-7	0.94	0.175	5.5	9.2	2.0	14.1	9.1	62	119
4T4-8	0.91	0.188	5.3	8.8	1.36	10.7	6.8	65	106
4T4-9	0.29	0.130	1.32	2.2	1.08	3.0	7.5	18.1	47
4T4-10	0.29	0.169	1.63	2.7	1.35	3.9	5.1	16.0	39
4T4-11	0.59	1.82	89.	148.	10.7	178.	50	850	1870
4T4-12	21.	2.2	118.	197.	13.8	260.	40	760	1950
4T4-13	-	-	-	-	-	-	-	-	64
4T4-14	-	-	-	-	-	-	-	-	220
4T4-15	-	-	-	-	-	-	-	-	760
4T4-16	-	-	-	-	-	-	-	-	3000
4T4-17	-	-	-	-	-	-	-	-	130
4T4-18	-	-	-	-	-	-	-	-	3200
4T4-19	-	-	-	-	-	-	-	-	750
4T4-20	-	-	-	-	-	-	-	-	200
4S1-1	-	-	-	-	<0.001	<0.001	<0.001	<0.001	#
4S2-1	-	-	-	-	0.005	0.005	0.026	0.026	0.126
4S3-1	-	-	-	-	<0.001	<0.001	<0.001	<0.001	#

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

- = measurement point not established.
/ = measurement not taken.
= measurement not possible.
* = data cannot be extrapolated.

TABLE D-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies
(page 1 of 2)

	1986				1987		1988		1989
SITE NO., MEAS.PT.	NS 4 amps	NEW 6 amps	SEW 6 amps	SEW 10 amps (EX)	NS 15 amps	EW 15 amps	NS 75 amps	EW 75 amps	B 150 amps
4C1-6	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	0.001	0.003
4C1-7	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002
4C1-8	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002
4C1-9	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	0.001	0.003
4C1-10	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002
4C1-11	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002
4C1-12	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002
4C1-13	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	0.001	0.003
4T2-3	0.047	0.001	0.22	0.37	0.008	0.55	0.040	2.8	5.7
4T2-4	0.049	0.001	0.24	0.40	0.008	0.57	0.041	2.9	5.8
4T2-5	0.197	<0.001	1.00	1.67	0.011	2.4	0.061	12.4	24
4T2-6	0.058	0.001	0.44	0.73	0.006	1.16	0.020	5.0	10.3
4T2-7	0.046	0.001	0.22	0.37	0.006	0.59	0.024	2.6	5.4
4T2-8	0.045	0.001	0.22	0.37	0.006	0.59	/	/	5.6
4T2-9	0.029	0.001	0.138	0.23	0.007	0.38	0.027	1.72	3.4
4T2-10	0.033	0.001	0.149	0.25	0.006	0.39	0.027	1.78	3.5
4T2-11	0.043	0.001	0.21	0.35	0.006	0.56	0.025	2.6	5.0
4T2-12	0.047	0.001	0.23	0.38	0.006	0.61	/	/	5.6
4T2-13	0.086	<0.001	0.43	0.72	0.005	1.14	0.020	5.1	10.1
4T2-14	0.21	<0.001	1.03	1.72	0.012	2.5	0.061	11.9	25
4T2-15	-	-	-	-	-	-	-	-	33
4T2-16	-	-	-	-	-	-	-	-	28
4T2-17	-	-	-	-	-	-	-		13.6
4T2-18	-	-	-	-	-	-	-	-	8.6
4T2-19	-	-	-	-	-	-	-	-	5.9

NS = north-south antenna
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

- = measurement point not established.
/ = measurement not taken.
= measurement not possible.
* = data cannot be extrapolated.

TABLE D-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

SITE NO., MEAS. PT.	1986 NS 4 amps	1986 NEW 6 amps	1986 SEW 6 amps	1986 SEW 10 amps (EX)	1987 NS 15 amps	1987 EW 15 amps	1988 NS 75 amps	1988 EW 75 amps	1989 B 150 amps
4T4-4	0.019	<0.001	0.096	0.160	0.005	0.24	0.027	1.15	2.5
4T4-5	0.114	0.001	0.57	0.95	0.008	1.40	0.033	6.9	13.9
4T4-6	0.045	0.001	0.22	0.37	0.008	0.53	0.034	2.7	5.3
4T4-7	0.038	0.001	0.186	0.31	0.008	0.45	0.033	2.3	4.4
4T4-8	0.035	0.001	0.179	0.30	0.007	0.43	0.033	2.1	4.2
4T4-9	0.025	0.21	0.118	0.197	0.005	0.29	0.027	1.41	2.8
4T4-10	0.022	<0.001	0.116	0.193	0.005	0.27	0.027	1.33	2.7
4T4-11	0.161	0.001	0.80	1.33	0.011	1.89	0.042	8.9	18.7
4T4-12	0.115	0.001	0.58	0.97	0.010	1.37	0.041	7.1	14.5
4T4-13	-	-	-	-	-	-	-	-	2.7
4T4-14	-	-	-	-	-	-	-	-	7.0
4T4-15	-	-	-	-	-	-	-	-	11.9
4T4-16	-	-	-	-	-	-	-	-	18
4T4-17	-	-	-	-	-	-	-	-	14.3
4T4-18	-	-	-	-	-	-	-	-	16.8
4T4-19	-	-	-	-	-	-	-	-	9.8
4T4-20	-	-	-	-	-	-	-	-	5.9
4S1-1	-	-	-	-	<0.001	<0.001	<0.001	<0.001	#
4S2-1	-	-	-	-	<0.001	<0.001	0.001	<0.001	0.002
4S3-1	-	-	-	-	<0.001	<0.001	<0.001	<0.001	#

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

\- = measurement point not established.
/ = measurement not taken.
\# = measurement not possible.
* = data cannot be extrapolated.

APPENDIX E

AQUATIC ECOSYSTEMS STUDIES

AQUATIC ECOSYSTEMS STUDIES

During September 1989, IITRI field crews made ELF electromagnetic (EM) field measurements at 19 measurement points at six treatment and five control sites for the aquatic ecosystems studies. The measurement points differed from those used in 1988; two points were added--one at the downstream end of the insect movement site (5C1-6) and the other where a 38 kV transmission line crosses the Ford River (5C15-1)--and one point was dropped (5T4-2).

The positions of the 11 sites relative to the NRTF-Republic are shown on the composite map in Figure E-1. The site numbers listed on the map are those used by IITRI. Table E-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are given in Figures E-2 through E-8.

The approach of the aquatic ecosystems studies is to integrate the major interrelated and interactive components of aquatic ecosystems (periphytic algae, aquatic insects, and fish) and to monitor events and processes critical to stream ecosystems. The electric field in the earth near the surface and the magnetic field are considered the most important factors influencing the aquatic ecosystems studies. The electric field in the air is not expected to have any impact on the components of these studies.

EM field measurements for 1989 and previous years are found in Tables E-2 through E-7. Tables E-2, E-3, and E-4 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables E-5, E-6, and E-7 present 76 Hz data for these fields at the corresponding operating currents of the NRTF-Republic for each year.

The 60 Hz EM fields measured at the study sites in 1989 are consistent with those measured in previous years. As anticipated, EM intensities at the new transmission line location (5C15-1) are the highest of the measured 60 Hz values.

The 1989, 76 Hz measurements were made with 150 ampere antenna currents, the predominant operating current of the NRTF-Republic since 4 May 1989. The EM exposures at the study sites for the period prior to 4 May can be estimated either by using the 75 ampere antenna current measurement data from 1988 or by using one-half the value of the 1989, 150 ampere data.

The EM field exposure ratios for the treatment/control site pairs were recalculated in 1989 for the aquatic ecosystems studies. These ratios are shown in Table E-8. As in the past, not all exposure ratios met the exposure ratio guidelines created for the establishment of study sites. These exceptions and the intended course of action are discussed in Section 4.3.2 of this report.

60237/790

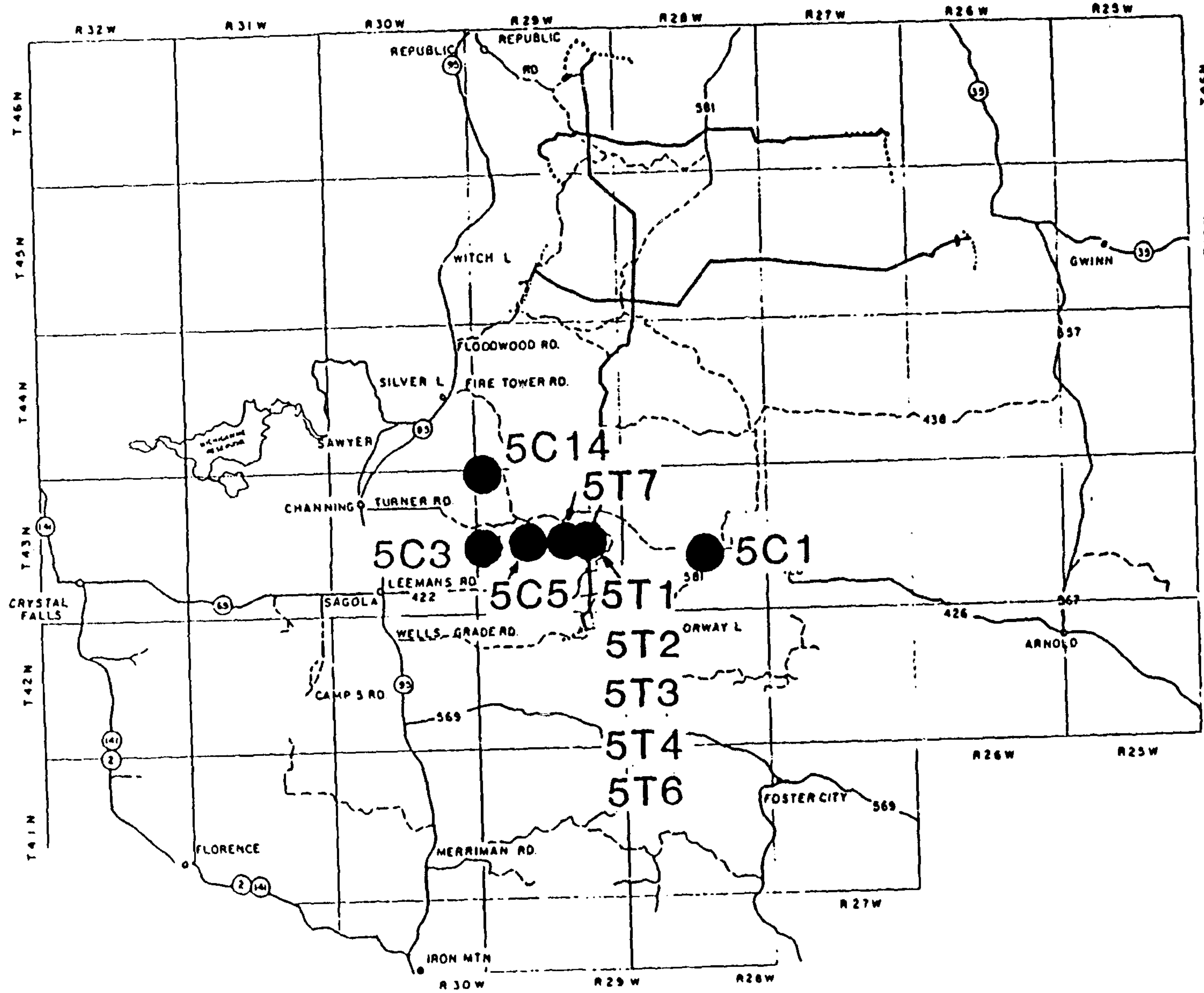


FIGURE E-1. POSITIONS OF AQUATIC ECOSYSTEMS STUDY SITES RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

TABLE E-1. SITE NO. CROSS-REFERENCE
Aquatic Ecosystems Studies

IITRI Site No.	Investigator's Site Name	Location: Township	:	Range	:	Section(s)
5T1-1*	FEX 1; Fish Parasites	T43N	:	R29W	:	11
5T1-2	FEX 1; Insect Substrates	T43N	:	R29W	:	14
5T2-1	FEX 2; Ambient Monitoring, Insect Movement, Periphyton Grazing	T43N	:	R29W	:	14
5T2-2	FEX 2; Periphyton	T43N	:	R29W	:	14
5T2-3	FEX 2; Insect Movement	T43N	:	R29W	:	14
5T3-1	FEX 3; Fish Population	T43N	:	R29W	:	14
5T4-1*	FEX 4; Fish Parasites	T43N	:	R29W	:	14
5T4-2*	FEX 4; Fish Feeding	T43N	:	R29W	:	14(11)
5T6-1*	FEX 6; Fish Parasites	T43N	:	R29W	:	13
5T7-1	FEX 7; Fish Population (future)	T43N	:	R29W	:	14
5C1-1	FCD; Ambient Monitoring	T43N	:	R28W	:	21
5C1-2*	FCD; Fish Parasites	T43N	:	R28W	:	21
5C1-3	FCD; Insect Movement	T43N	:	R28W	:	21
5C1-4	FCD; Fish Population	T43N	:	R28W	:	21
5C1-5	FCD; Insect Substrates, Periphyton, Periphyton Grazing	T43N	:	R28W	:	21
5C1-6	FCD; Insect Movement	T43N	:	R28W	:	21
5C3-2	FCU; Fish Population	T43N	:	R29W	:	18
5C5-1	FSI; Fish Population	T43N	:	R29W	:	16
5C14-1	TM; Fish Population	T43N	:	R29W	:	8
5C15-1	Fish Population (at T-Line)	T43N	:	R29W	:	17

*Location is currently inactive.

60297/790

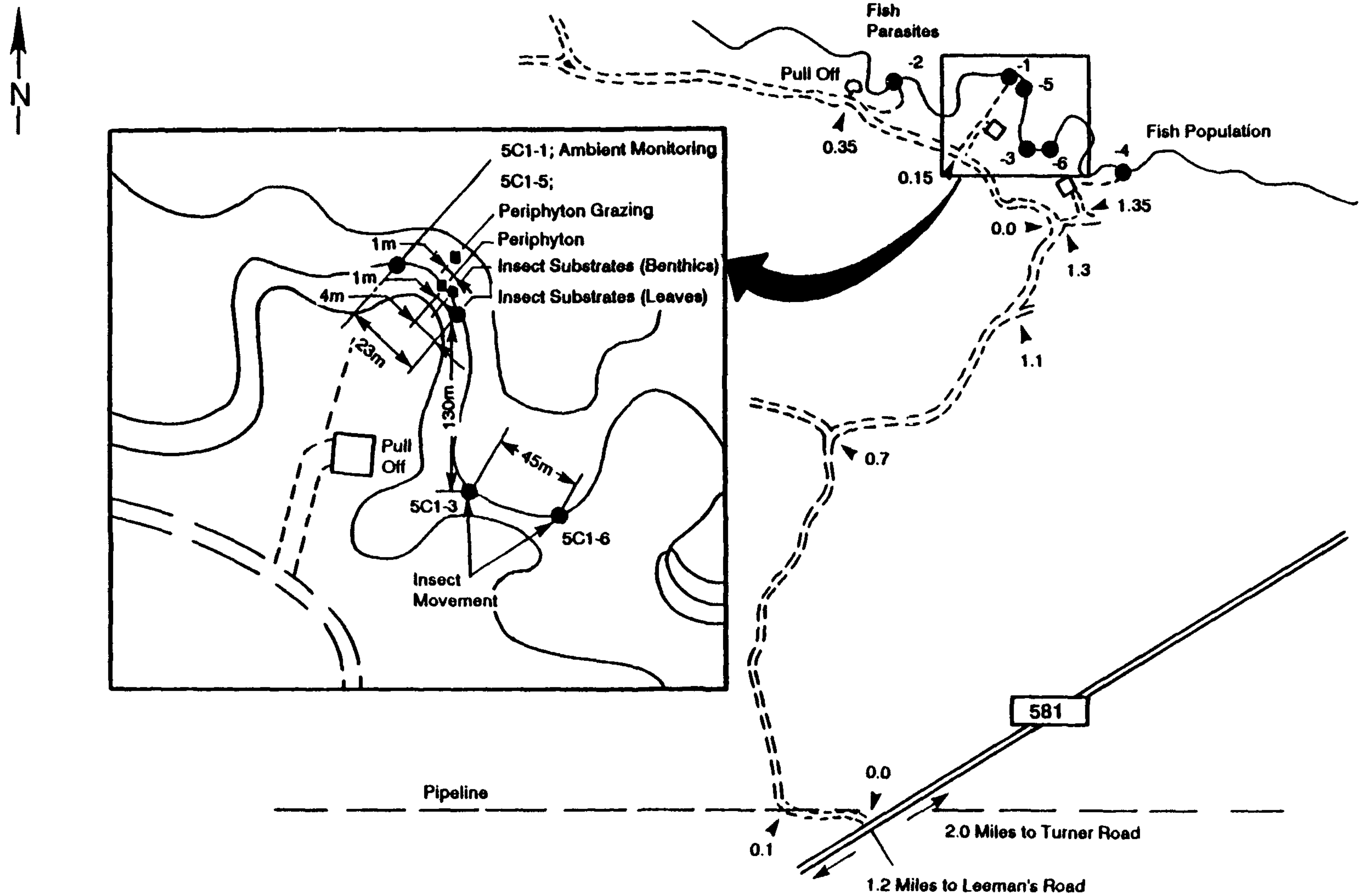


FIGURE E-2. MEASUREMENT POINTS AT FCD; 5C1-1 THROUGH 6

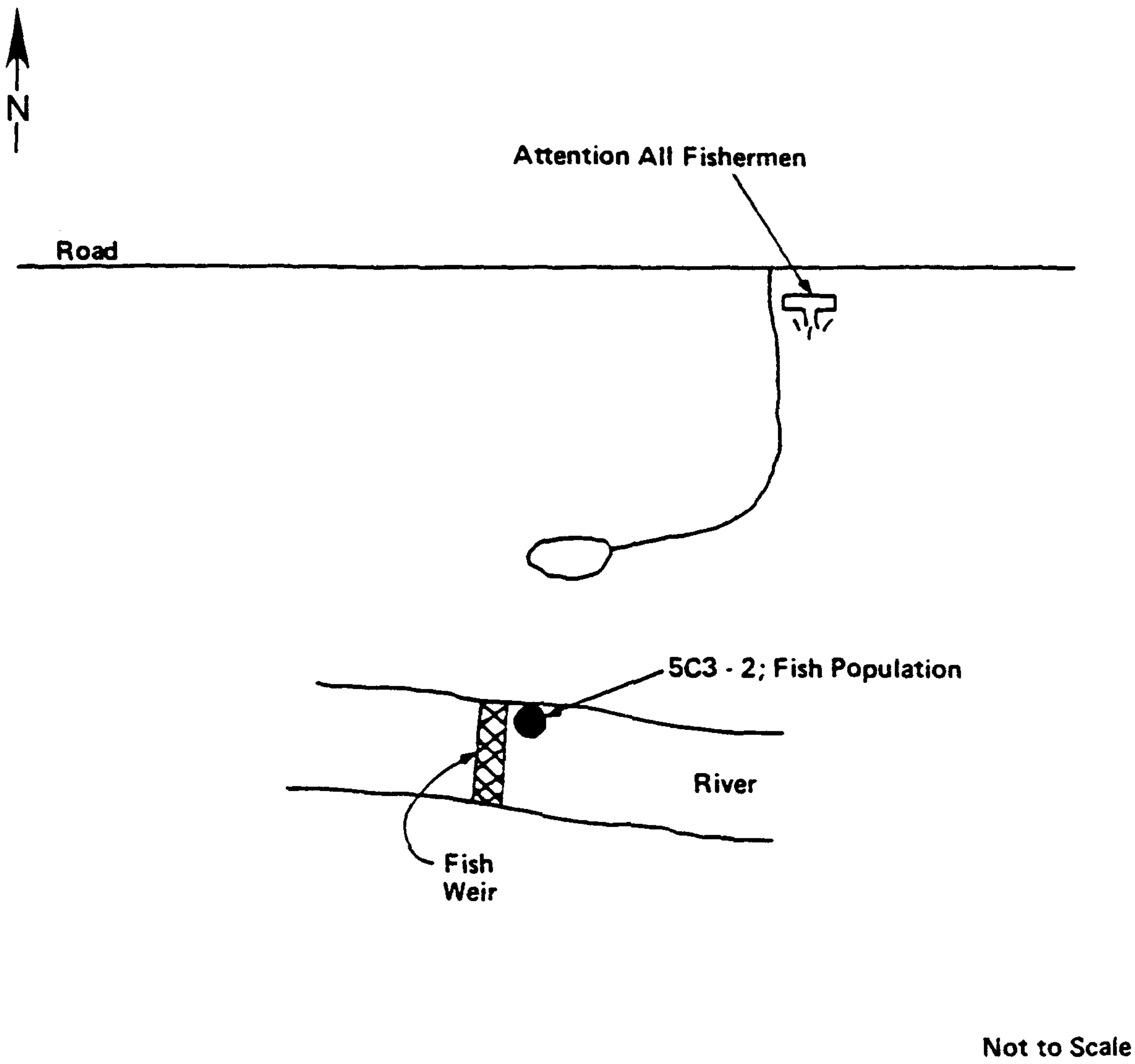


FIGURE E-3. MEASUREMENT POINT AT FCU; 5C3-2.

60297/190

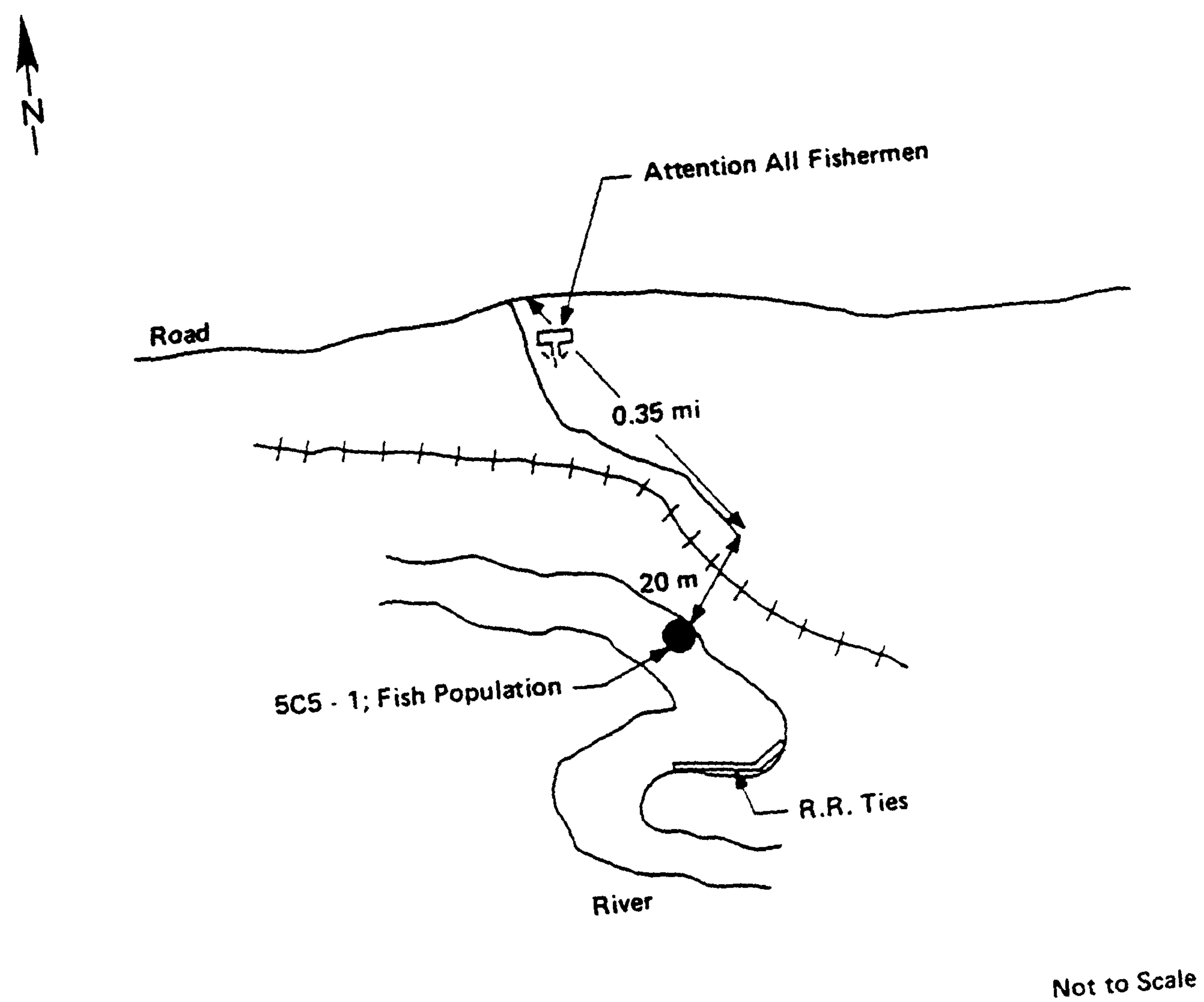


FIGURE E-4. MEASUREMENT POINT AT FS1; 5C5-1.

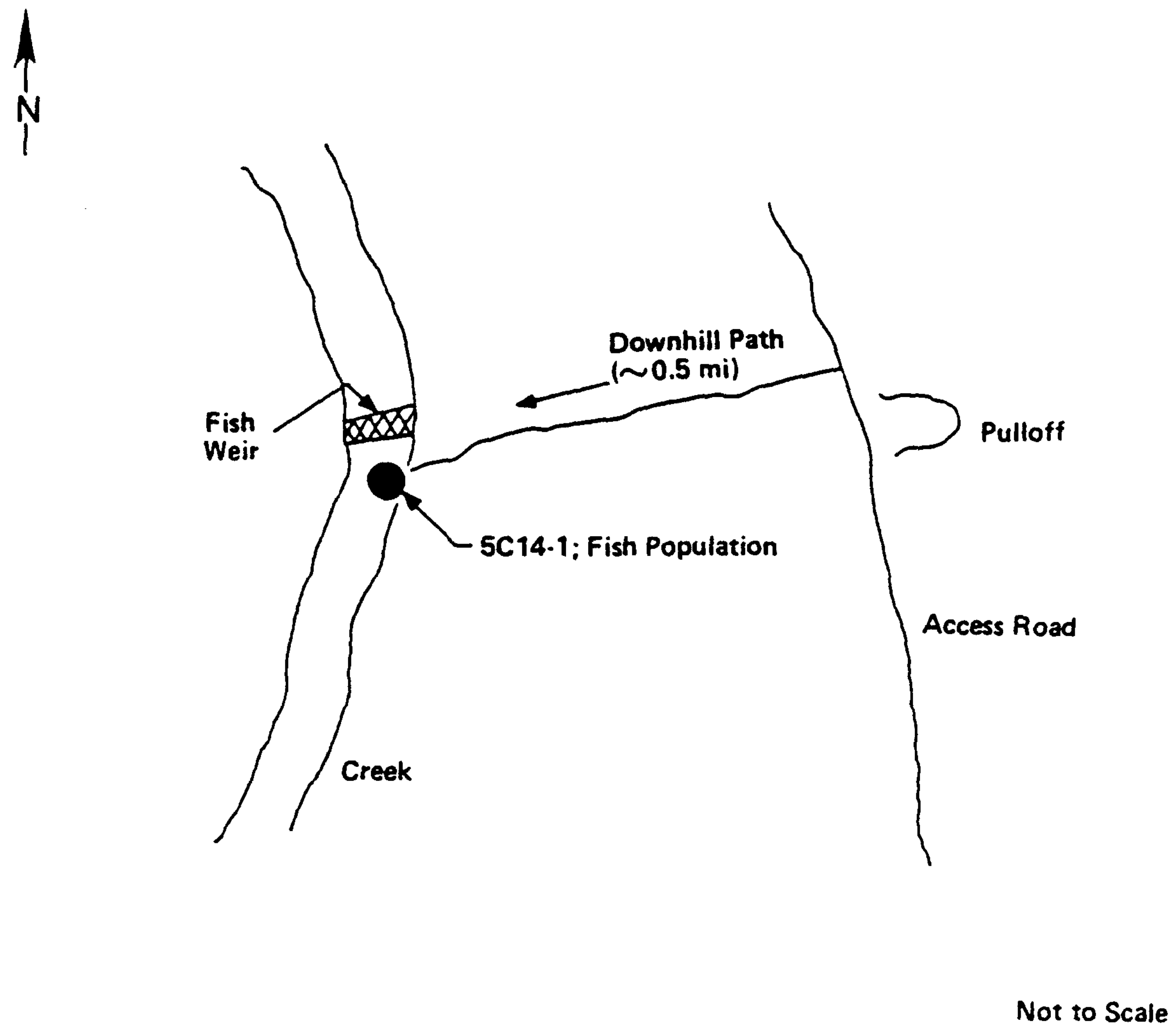


FIGURE E-5. MEASUREMENT POINT AT TM; 5C14-1.

60297/790

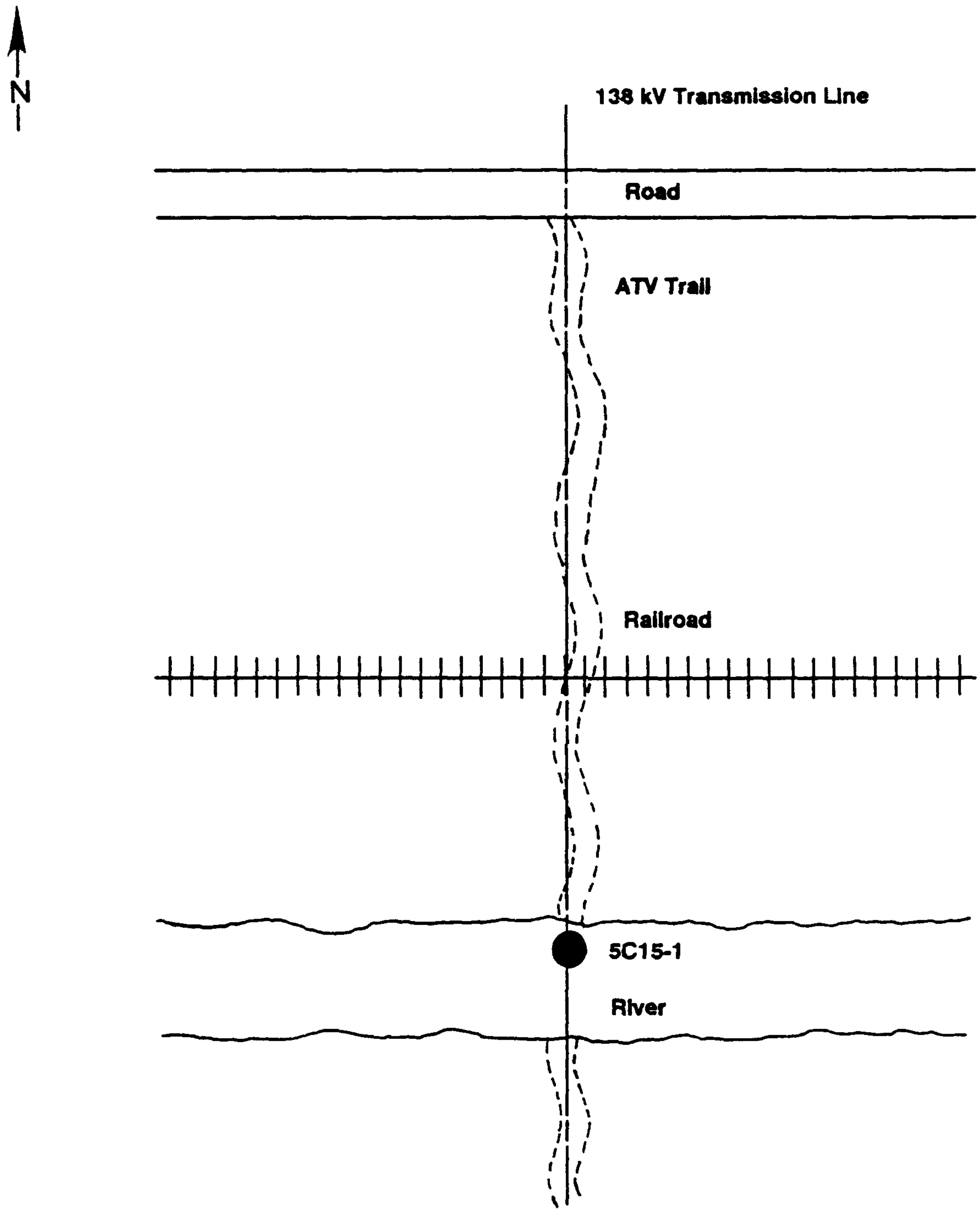


FIGURE E-6. MEASUREMENT POINT AT 5C15-1.

60297/790

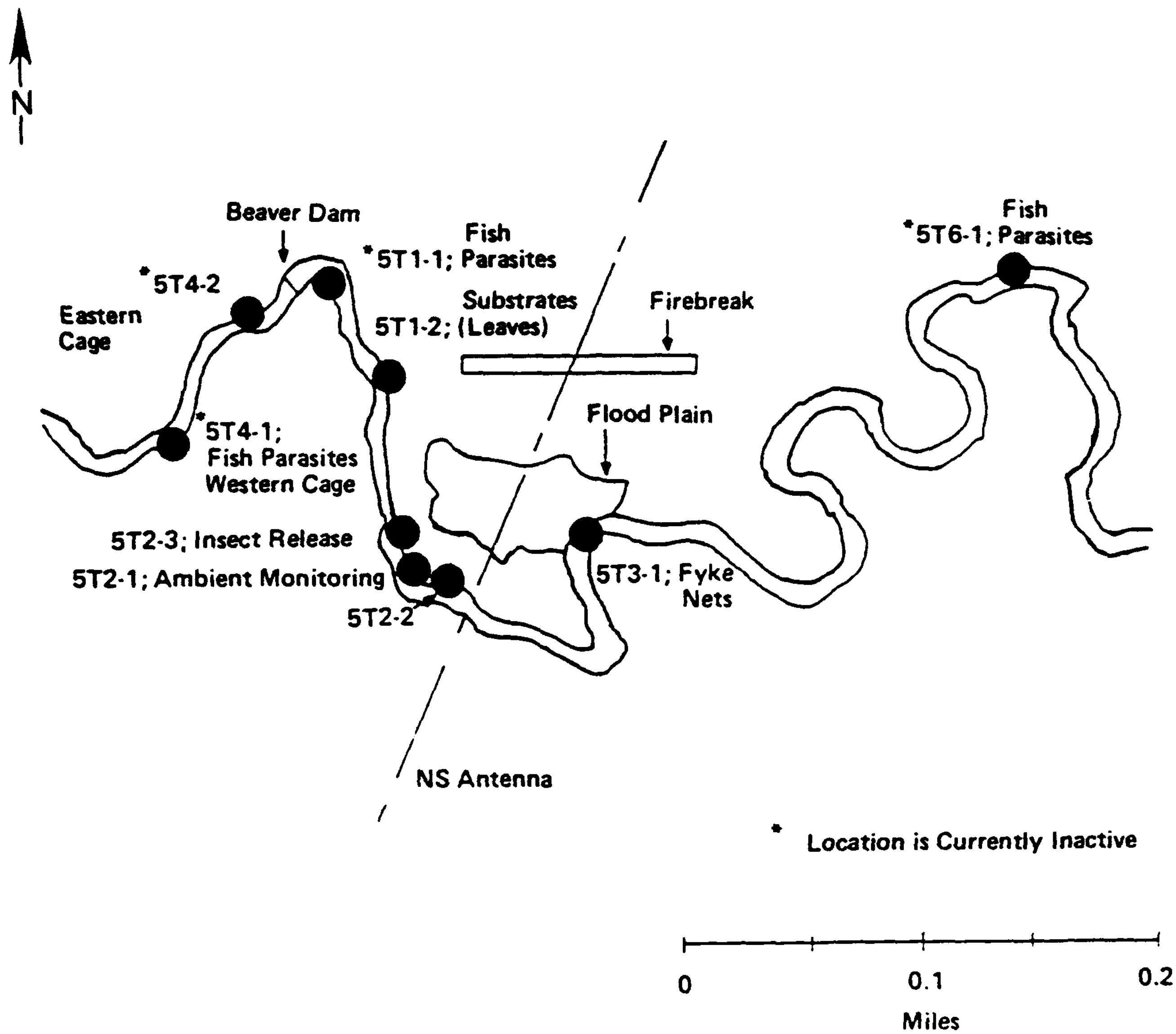


FIGURE E-7. MEASUREMENT POINTS AT FEX 1, FEX 2, FEX 4, FEX 6; 5T1-1, 5T2-1, 2, 3; 5T3-1; 5T4-1, 2; 5T6-1.

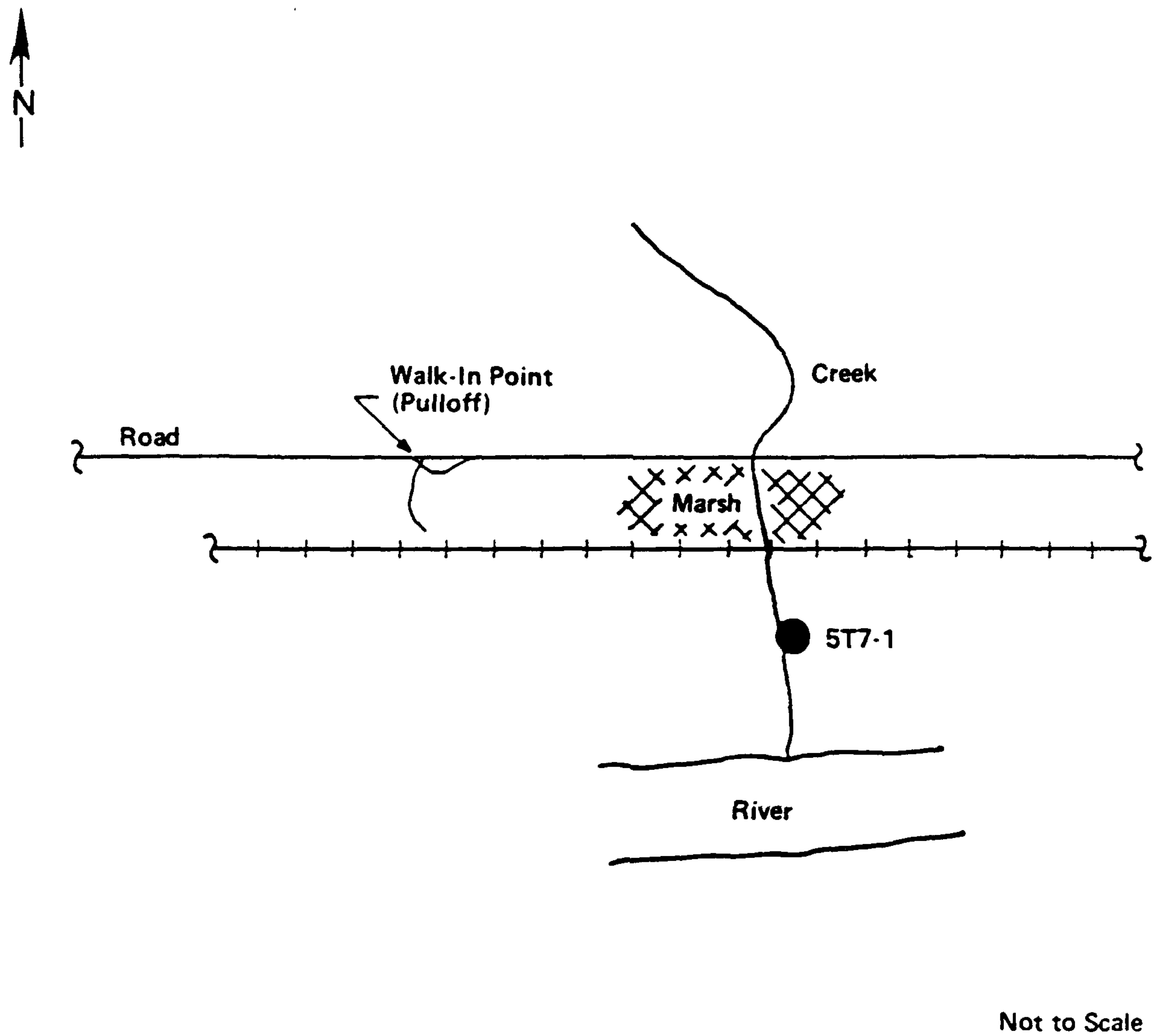


FIGURE E-8. MEASUREMENT POINT AT FEX 7; 5T7-1.

TABLE E-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Aquatic Ecosystems Studies

Site No., Meas. Pt.	1983 [a]	1984 [a]	1985 [a]	1986 [b]	1987 [c]	1988 [c]	1989 [d]
5C1-1	0.002	<0.001	<	<	<	<	<
5C1-2	<0.001	/	/	<	<	<	<
5C1-3	<0.001	/	/	<	<	<	<
5C1-4	-	<0.001	<	<	<	<	<
5C1-5	-	-	-	-	-	<	<
5C1-6	-	-	-	-	-	-	<
5C3-2	<0.001	0.003	<	<	<	<	<
5C5-1	0.001	<0.001	<	<	<	<	<
5C14-1	-	0.033	<	<	<	<	<
5C15-1	-	-	-	-	-	-	6.5
5T1-1	-	/	/	<	<	<	<
5T1-2	<0.001	<	<	<	<	<	<
5T2-1	-	<	<	<	<	<	<0.001
5T2-2	-	<	<	<	<0.001	0.002	<0.001
5T2-3	-	-	-	<	<	<0.001	<
5T3-1	-	<	<	<	0.001	<0.001	/
5T4-1	-	<	/	<	<	<	<
5T4-2	-	-	-	<	<	<	--
5T6-1	-	<0.001	<	<	<	<0.001	<
5T7-1	-	-	-	<	<	<0.001	<

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
= measurement not possible.
< = est. <0.001 V/m based on E-field in ground.

TABLE E-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITES (mV/m)
Aquatic Ecosystems Studies

Site No., Meas. Pt.	1983 [a]	1984 [a]	1985 [a]	1986 [b]	1987 [c]	1988 [c]	1989 [d]
5C1-1	1.47,1.73	2.7	2.6	0.22	0.26	0.32	0.27
5C1-2	1.8	/	/	0.155	0.160	0.21	0.21
5C1-3	1.3	/	/	0.126	0.148	0.179	0.22
5C1-4	-	2.5,2.7	2.2	0.174	0.25	0.21	0.44
5C1-5	-	-	-	-	-	0.27	0.33
5C1-6	-	-	-	-	-	-	0.22
5C3-2	0.049	0.045	0.060	0.119	0.079	0.110	0.110
5C5-1	0.076	0.062	0.059	0.077	0.118	0.140	0.029
5C14-1	-	0.174,0.24	0.22	0.187	0.31	0.41	1.27
5C15-1	-	-	-	-	-	-	1.4
5T1-1	0.38	0.38	/	0.125	0.062	0.093	0.26
5T1-2	0.184	0.154,0.22	0.175	0.037	0.032	0.044	0.048
5T2-1	-	0.22,0.31	0.23	0.057	0.061	0.126	0.037
5T2-2	-	0.26	0.165	0.082	0.076	0.198	0.040
5T2-3	-	-	-	0.050	0.056	0.063	0.033
5T3-1	-	0.22,0.26	0.23	0.046	0.053	0.115	/
5T4-1	-	0.170,0.195	/	0.032	0.028	0.035	0.099
5T4-2	-	-	-	0.073	0.048	0.064	--
5T6-1	-	0.37,0.42	0.34	0.047	0.043	0.116	/
5T7-1	-	-	-	0.040	0.012	0.053	/

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
= measurement not possible.

TABLE E-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Aquatic Ecosystems Studies

Site No., Meas. Pt.	a 1983	a 1984	a 1985	b 1986	c 1987	c 1988	d 1989
5C1-1	0.008	0.008	0.003	0.001	0.001	0.001	0.001
5C1-2	0.006	/	/	0.001	0.001	<0.001	0.001
5C1-3	0.004	/	/	0.001	0.001	0.001	0.001
5C1-4	-	0.007,0.008	0.007	0.001	0.001	0.001	0.002
5C1-5	-	-	-	-	-	<0.001	0.001
5C1-6	-	-	-	-	-	-	0.001
5C3-2	0.003	0.003	0.003	0.005	0.004	0.009	0.008
5C5-1	0.002	0.002	0.002	0.001	0.001	0.002	<0.001
5C14-1	-	0.013.0.021	0.020	0.017	0.094	0.034	0.057
5C15-1	-	-	-	-	-	-	4.4
5T1-1	<0.001	<0.001	/	0.002	0.003	<0.001	0.006
5T1-2	<0.001	0.001	0.001	0.004	0.005	0.001	0.008
5T2-1	-	0.001,0.002	0.001	0.005	0.009	0.015	0.003
5T2-2	-	0.002	0.001	0.014	0.021	0.047	0.009
5T2-3	-	-	-	0.004	0.007	0.007	0.003
5T3-1	-	0.001,0.002	0.001	0.005	0.009	0.021	/
5T4-1	-	0.001	/	<0.001	0.002	<0.001	0.004
5T4-2	-	-	-	0.001	0.002	<0.001	--
5T6-1	-	0.001	0.001	0.001	0.002	0.003	/
5T7-1	-	-	-	0.001	0.001	0.005	/

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
\# = measurement not possible.

TABLE E-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Aquatic Ecosystems Studies

SITE NO., MEAS.PT.	1986 NS 4 amps	1986 NEW 6 amps	1986 SEW 6 amps	1986 SEW 10 amps (EX)	1987 NS 15 amps	1987 EW 15 amps	1988 NS 75 amps	1988 EW 75 amps	1989 B 150 amps
5C1-1	<	<	<	*	<	<	<	<	<
5C1-2	<	<	<	*	<	<	<	<	<
5C1-3	<	<	<	*	<	<	<	<	<
5C1-4	<	<	<	*	<	<	<	<	<
5C1-5	-	-	-	-	-	-	<	<	<
5C1-6	-	-	-	-	-	-	-	-	<
5C3-2	<	<	<	*	<	<	<	<	<
5C5-1	<	<	<	*	<	<	<	<	<
5C14-1	<	<	<	*	<	<	<	<	<
5C15-1	-	-	-	-	-	-	-	-	#
5T1-1	<	<	<	*	0.009	<	0.037	0.001	0.091
5T1-2	<	<	<	*	<0.001	<	0.014	0.002	0.029
5T2-1	0.001	<	<	*	0.005	<	0.026	0.002	0.062
5T2-2	0.011	<	<	*	0.022	<0.001	0.130	<0.001	0.54
5T2-3	<	<	<	*	0.005	<	0.030	<0.001	0.049
5T3-1	0.008	<	<	*	0.020	<	0.104	<0.001	0.175
5T4-1	<	<	<	*	0.003	<	0.014	<0.001	0.036
5T4-2	<	<	<	*	0.007	<	0.054	<0.001	--
5T6-1	<	<	<	*	0.006	<	0.035	0.002	0.057
5T7-1	<	<	<	*	/	<	0.014	<0.001	0.029

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
= measurement not possible.
< = est <0.001 V/m based on E-field in ground.
* = data cannot be extrapolated.

TABLE E-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Aquatic Ecosystems Studies

	1986				1987		1988		1989
SITE NO., MEAS.PT.	NS 4 amps	NEW 6 amps	SEW 6 amps	SEW 10 amps (EX)	NS 15 amps	EW 15 amps	NS 75 amps	EW 75 amps	B 150 amps
5C1-1	0.33	0.020	0.052	0.087	1.33	0.158	6.8	0.81	11.7
5C1-2	0.24	0.016	0.053	0.088	1.07	0.186	4.9	0.76	9.9
5C1-3	0.191	0.013	0.047	0.078	0.85	0.130	4.1	0.73	7.6
5C1-4	0.26	0.014	0.075	0.125	1.02	0.160	4.6	0.64	10.5
5C1-5	-	-	-	-	-	-	7.1	0.83	11.9
5C1-6	-	-	-	-	-	-	-	-	7.7
5C3-2	0.013	0.002	0.007	0.012	0.067	0.023	0.26	0.091	0.58
5C5-1	0.034	0.002	0.009	0.015	0.138	0.035	0.68	0.150	1.39
5C14-1	0.042	0.004	0.015	0.025	0.183	0.055	0.81	0.25	1.86
5C15-1	-	-	-	-	-	-	-	-	#
5T1-1	2.5	0.080	0.108	0.180	7.5	0.33	46	1.47	98
5T1-2	0.77	0.034	0.097	0.162	2.9	0.30	16.1	1.61	27
5T2-1	1.33	0.045	0.077	0.128	5.4	0.22	25	1.16	47
5T2-2	1.62	0.052	0.067	0.112	6.1	0.184	31	0.100	65
5T2-3	1.17	0.042	0.079	0.132	4.9	0.23	21	1.18	40
5T3-1	1.22	0.045	0.082	0.137	4.8	0.27	18.8	1.07	45
5T4-1	0.75	0.026	0.061	0.102	3.0	0.182	17.3	1.06	35
5T4-2	1.91	0.056	0.077	0.128	5.3	0.21	37	1.06	--
5T6-1	1.21	0.030	0.066	0.110	4.5	0.20	24	0.96	45
5T7-1	0.76	0.033	0.072	0.120	2.6	0.189	15.3	1.09	9.4

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.

EX = extrapolated data.
\- = measurement point not established.
-- = measurement point dropped.
= measurement not possible.

TABLE E-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Aquatic Ecosystems Studies

SITE NO., MEAS.PT.	1986 NS 4 amps	1986 NEW 6 amps	1986 SEW 6 amps	1986 SEW 10 amps (EX)	1987 NS 15 amps	1987 EW 15 amps	1988 NS 75 amps	1988 EW 75 amps	1989 B 150 amps
5C1-1	0.001	<0.001	<0.001	*	0.005	0.001	0.022	0.005	0.039
5C1-2	0.001	<0.001	<0.001	*	0.005	0.001	0.022	0.005	0.038
5C1-3	0.001	<0.001	<0.001	*	0.005	0.001	0.022	0.005	0.038
5C1-4	0.001	<0.001	<0.001	*	0.005	0.001	0.022	0.005	0.040
5C1-5	-	-	-	-	-	-	0.022	0.005	0.038
5C1-6	-	-	-	-	-	-	-	-	0.038
5C3-2	0.001	<0.001	<0.001	*	0.003	0.001	0.016	0.004	0.038
5C5-1	0.003	<0.001	0.001	0.002	0.013	0.002	0.061	0.007	0.138
5C14-1	0.001	<0.001	<0.001	*	0.005	0.001	0.024	0.004	0.060
5C15-1	-	-	-	-	-	-	-	-	#
5T1-1	0.045	0.001	<0.001	*	0.170	0.002	0.81	0.006	1.79
5T1-2	0.063	0.002	<0.001	*	0.25	0.002	1.19	0.006	2.3
5T2-1	0.129	0.004	0.001	0.002	0.50	0.002	2.3	0.008	4.8
5T2-2	0.31	0.009	0.001	0.002	1.20	0.003	5.5	0.018	12.7
5T2-3	0.110	0.003	<0.001	*	0.41	0.002	1.90	0.007	3.7
5T3-1	0.137	0.004	0.001	0.002	0.51	0.001	2.6	0.014	5.1
5T4-1	0.028	0.001	<0.001	*	0.118	0.002	0.58	0.007	1.17
5T4-2	0.033	0.001	<0.001	*	0.123	0.002	0.60	0.006	--
5T6-1	0.029	0.001	0.001	0.002	0.109	0.002	0.51	0.008	1.03
5T7-1	0.011	<0.001	0.001	0.002	0.040	0.002	0.20	0.008	0.40

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.

EX = extrapolated data.
- = measurement point not established.
-- = measurement point dropped.
= measurement not possible.
* = data cannot be extrapolated.

TABLE E-8. EM FIELD INTENSITY RATIOS
Aquatic Ecosystems Studies

Compared Sites	Activity	Transverse E-Field				Longitudinal E-Field				Magnetic Flux Density			
		R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
5T1-2/5C1-5	Insect Substrates	29	29	29	1.00	2.3	560	82	0.145	61	290	2300	8.0
5T2-2/5C1-5	Periphyton	540	540	540	1.00	5.5	1630	200	0.121	330	1410	12700	9.0
5T2-1/5C1-5	Periphyton Grazing	62	62	62	1.00	3.9	1270	142	0.112	126	1600	4800	3.0
5T2-1/5C1-3	Insect Movement	62	62	62	1.00	6.2	1270	210	0.168	126	1600	4800	3.0
5T2-1/5C1-6	Insect Movement	62	62	62	1.00	6.1	1270	210	0.168	126	1600	4800	3.0
5T2-3/5C1-3	Insect Movement	49	49	49	1.00	5.3	1210	182	0.150	97	1230	3700	3.0
5T2-3/5C1-6	Insect Movement	49	49	49	1.00	5.2	1210	182	0.150	97	1230	3700	3.0
5T3-1/5C1-4	Fish Population	175	175	175	1.00	4.3	390	102	0.26	128	240	2600	10.5
5T3-1/5C3-2	Fish Population	175	175	175	1.00	78	390	410	1.05	134	240	640	2.6
5T3-1/5C5-1	Fish Population	175	175	175	1.00	32	390	1550	4.0	37	240	5100	21
5T3-1/5C14-1	Fish Population	175	175	175	1.00	24	390	35	0.091	85	240	89	0.37

R1 = T(76) / C(76), should be > 10.

R2 = T(76) / T(60), should be > 10.

R3 = T(76) / C(60), should be > 10.

R4 = T(60) / C(60), should be > 0.1 and < 10.

APPENDIX F

SOIL AMOEBA STUDIES

SOIL AMOEBA STUDIES

During September 1989, IITRI field crews made ELF electromagnetic (EM) field measurements at nine measurement points at two treatment sites and one control site for the soil amoeba studies. The study sites and the measurement points within those sites were unchanged from 1988.

The positions of the study sites relative to the NRTF-Republic are shown on the composite map in Figure F-1. The site numbers listed on the map are those used by IITRI. Table F-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are shown in Figures F-2 through F-4.

TABLE F-1. SITE NO. CROSS-REFERENCE
Soil Amoeba Studies

IITRI Site No.	Investigator's Site Name	Location		
		Township	Range	Section(s)
6T3	Leeman's Road	T43N	R29W	23
6T4	Wells Grade Ground	T42N	R29W	2
6C2	Merriman Truck Trail Control	T41N	R29W	21

The objectives of these studies are to monitor population and species characteristics, cell cycle, cropping efficiency, and distribution in the soil. The electric and magnetic fields in the earth are considered the most important EM factors to be examined. The electric field in the air is not expected to have a significant impact on the objectives of these studies.

EM field measurements for 1989 and previous years are found in Tables F-2 through F-7. Tables F-2, F-3, and F-4 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables F-5, F-6, and F-7 present 76 Hz data for these fields at the corresponding operating currents of the NRTF-Republic for each year.

The 60 Hz EM fields measured at the study sites in 1989 are consistent with those measured in previous years.

The 1989, 76 Hz measurements were made with 150 ampere antenna currents, the predominant operating current of the NRTF-Republic since 4 May 1989. The EM exposures at the study sites for the period prior to 4 May can be estimated either by using the 75 ampere antenna current measurement data from 1988 or by using one-half the value of the 1989, 150 ampere data.

Microprocessor-controlled data loggers were installed at all soil amoeba study sites in early July 1988. These data loggers measured earth electric field intensities, culture cell voltages and currents, and the temperature inside the partially buried data logger housing. The data loggers have been kept at the study sites since their installation except for a period of about three months in early 1989, when they were removed for the addition of two soil temperature probes and other maintenance and modifications. The data logger measurement protocols used at treatment and control study sites in 1988 and 1989 are described below.

1988 Data Logger Measurement Protocol

- Hourly culture cell electric field and current density, earth electric field, and temperature measurements were made.
- 76 Hz EM fields from the NS antenna were measured with the EW antenna off.
- 76 Hz EM fields from the EW antenna were measured with the NS antenna off.
- Ambient 60 Hz EM fields were measured with both antennas off.
- All measurements were made with a wide bandwidth meter, knowing that the intended measurement frequency would dominate other frequencies.

At Treatment Study Sites

- Tests for operation of the NS antenna were performed by comparing the earth electric field to a threshold level for operation of the NS antenna.
- Operation of the EW antenna and the condition of both antennas off were assumed to follow operation of the NS antenna according to the normal 15-minute rotational operating pattern used in 1988.
- In hours when the NS antenna did not operate, the only measurements made were those for the condition of both antennas off.

At the Control Study Site

- Antenna operating conditions could not be tested for by means of the above threshold method. Instead, antenna operating conditions were determined by assuming that the normal 15-minute rotational operating pattern used in 1988 was synchronized on the hour, which was the standard operating procedure.

1989 Data Logger Measurement Protocol

- Hourly culture cell electric field and current density, earth electric field, and temperature measurements were made.

At Treatment Study Sites

- 76 Hz EM fields were measured with both antennas on.
- Ambient 60 Hz EM fields were measured with both antennas off.

- All measurements were made with a wide bandwidth meter, knowing that the intended measurement frequency would dominate other frequencies.
- Tests for the above measurement conditions were performed by comparing the earth electric field to a threshold level for antenna operation. Measurements were not taken in hours when stated measurement conditions were absent.

At the Control Study Site

- EM fields were measured first with, and then without, a 60 Hz notch filter, using a wide bandwidth meter.

Graphic Data Presentation

Graphs of 1988 data logger measurements appear in Figures F-5 through F-20. Figures F-5 through F-10 and F-13 through F-18 show the hourly EM fields for the six test cells at the antenna and ground study sites. Plots of hourly earth electric field measurements for the antenna and ground sites in 1988 are presented in Figures F-11, F-12, F-19, and F-20. Precipitation and temperature data appear below all graphs. These data were obtained from the National Weather Service at the Marquette County airport.

Antenna operating frequencies are indicated by 44 Hz or 76 Hz along the horizontal axis of the plots. From July 6 through July 13, the NRTF-Republic was undergoing tests at several operating frequencies. Because it would have been cumbersome to show each frequency change during this testing period, the graphs show only two major frequency bands: 44 Hz is shown to indicate testing at 40, 42, 44, 46, or 48 Hz; 76 Hz is shown to indicate testing at a frequency of 72, 74, 76, 78, or 80 Hz. After July 13, the NRTF-Republic operated only at 44 Hz or 76 Hz.

Graphs of 1989 data logger measurements are not included in this report. Although these data have been collected and reviewed, further tests are needed to explain variations that were present in the measurements. Presentation of the data before these additional tests are completed could be misleading, and therefore has been deferred.

Variations in the Earth Electric Field

There are two sources of the earth electric field associated with the ELF Communications System: the electric field induced by the magnetic field, and the electric field generated by ground terminal currents. The magnetically induced electric field is directly proportional to frequency and inversely proportional to the natural logarithm of the square root of the bulk earth conductivity. Magnetic induction is the dominant source of earth electric fields at the antenna study site. Because the bulk earth conductivity is relatively unaffected by surface moisture, the earth electric fields at the antenna site are expected

to vary primarily with the antenna operating frequency. This frequency dependence can be clearly seen in Figures F-11 and F-12 between periods of 76 and 44 Hz operation.

The earth electric field at the ground study site is sourced both by ground terminal currents and magnetic induction. The electric field generated by ground terminal currents is independent of frequency, but is inversely proportional to the surface earth conductivity. The surface earth conductivity, unlike the bulk earth conductivity, may undergo significant changes with variations in rainfall and temperature. The earth electric field at the ground study site is therefore expected to be more sensitive to weather changes than the earth electric field at the antenna study site. The surface earth conductivity also has a stronger functional relationship (inversely proportional as opposed to inverse-log-square root) to the earth electric field generated by ground terminal currents than the relationship of the bulk earth conductivity to the magnetically induced earth electric field. This is discussed in more detail in Section 4.5 of this report. The frequency dependence of the earth electric field at the ground site is less than that at the antenna study site because the magnetically induced electric field represents only a portion of the total earth electric field near a ground terminal. Figures F-19 and F-20 show the dependence of the earth electric field at the ground study site on frequency, rainfall, and temperature.

On July 22, the current distribution through the ground wire adjacent to the ground study site was reduced from 20.5 to 9 amperes. This resulted in a decrease in the earth electric field at the ground study site. The time of the change is marked in Figures F-13 through F-20 with a broken vertical line, and its effect can be seen in each of these figures.

Weather data are presented to explain some temporal variations of the earth electric field at the study sites. The data on electric field versus time suggest that the seasonal field variations at the antenna study site are on the order of ±5% if frequency changes are ignored. These variations show no evident dependence on rainfall or temperature, which is expected, since the bulk earth conductivity is not greatly affected by surface moisture or temperature. The electric fields near the ground study site are more sensitive to surface conductivity changes in the earth, and are therefore expected to show greater seasonal variations than are the electric fields at the antenna study site. Indeed, the earth electric fields at the ground study site show variations approaching ±20% when frequency and ground current distribution changes are factored out. Figures F-19 and F-20 show the correlation of changes in earth electric field at the ground study site with rainfall. As soil moisture content increases, soil conductivity increases, and the earth electric fields decrease. This is particularly evident in early August, as rainfall ended a period of drought.

Variations in the Culture Cell EM Fields

The culture cells at the study sites are driven by the earth electric field collected by buried electrodes near the cells. The drive voltages and resulting EM fields at the culture cells are therefore subject to the same variations as found in the earth electric field. Namely, changes in the culture cell EM fields are expected to be seen with changes in the antenna operating frequency, rainfall, and antenna configuration changes such as the redistribution of ground currents at ground #4 in July 1988.

For the matched current density cells at the antenna and ground study sites, variations in the measured current densities appear to be completely attributable to changes in the earth electric field. This relationship is illustrated by comparing the current density plots (Figures F-5, F-6, F-7, F-13, F-14, and F-15) with plots of the earth electric field from the corresponding sites (Figures F-11, F-12, F-19, and F-20), noting the difference in time scales. The temporal variations in the earth electric fields and current densities are similar. Small differences that do exist are explained by the fact that electrodes used in measuring the earth electric field are in a different physical location from the collector electrodes used to drive the culture cells. The electrodes used to measure the earth electric field were positioned to bound the borders of the study sites, while the collector electrodes were positioned within these boundaries.

The electric field intensities at the matched electric field cells show much more variability than the current densities at the matched current density cells. These variations at the matched electric field cells are not fully explained by changes in the earth electric field at the sites. However, changes in the impedance of the culture cell growth medium itself may explain this additional variability. The fraction of the electrode drive voltage that is impressed across the cell is determined by the ratio of the cell impedance to the sum of the cell impedance and that of the current sense resistor. If the cell impedance changes, the voltage across the cell, and hence its electric field, will change accordingly. The cell impedance can be affected by culture growth, temperature, and moisture changes. The fill level of the cell will also have a direct impact on the impedance of the cell, because cell impedance is a function of the cross-sectional area of the culture medium. All matched electric field cells exhibited a diurnal decrease in electric field that can be graphically correlated with temperature changes during the day.

The matched current density cells are subject to the same cell impedance changes as the matched electric field cells. However, their effects on the cell current densities are small because the impedances of the cells are very small relative to the impedances of the current sense resistors used to match current densities.

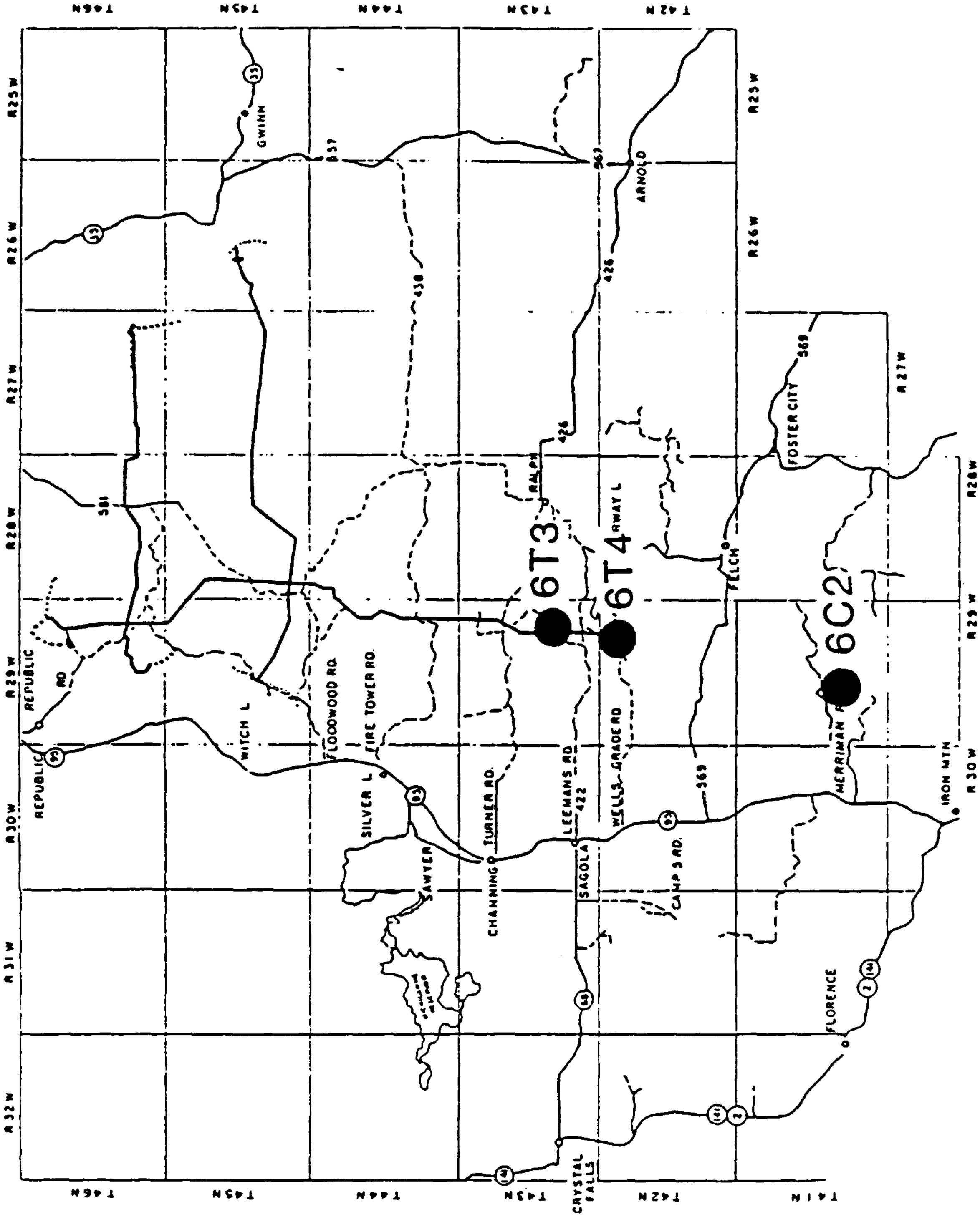


FIGURE F-1. POSITIONS OF SOIL AMOEBA STUDY SITES RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

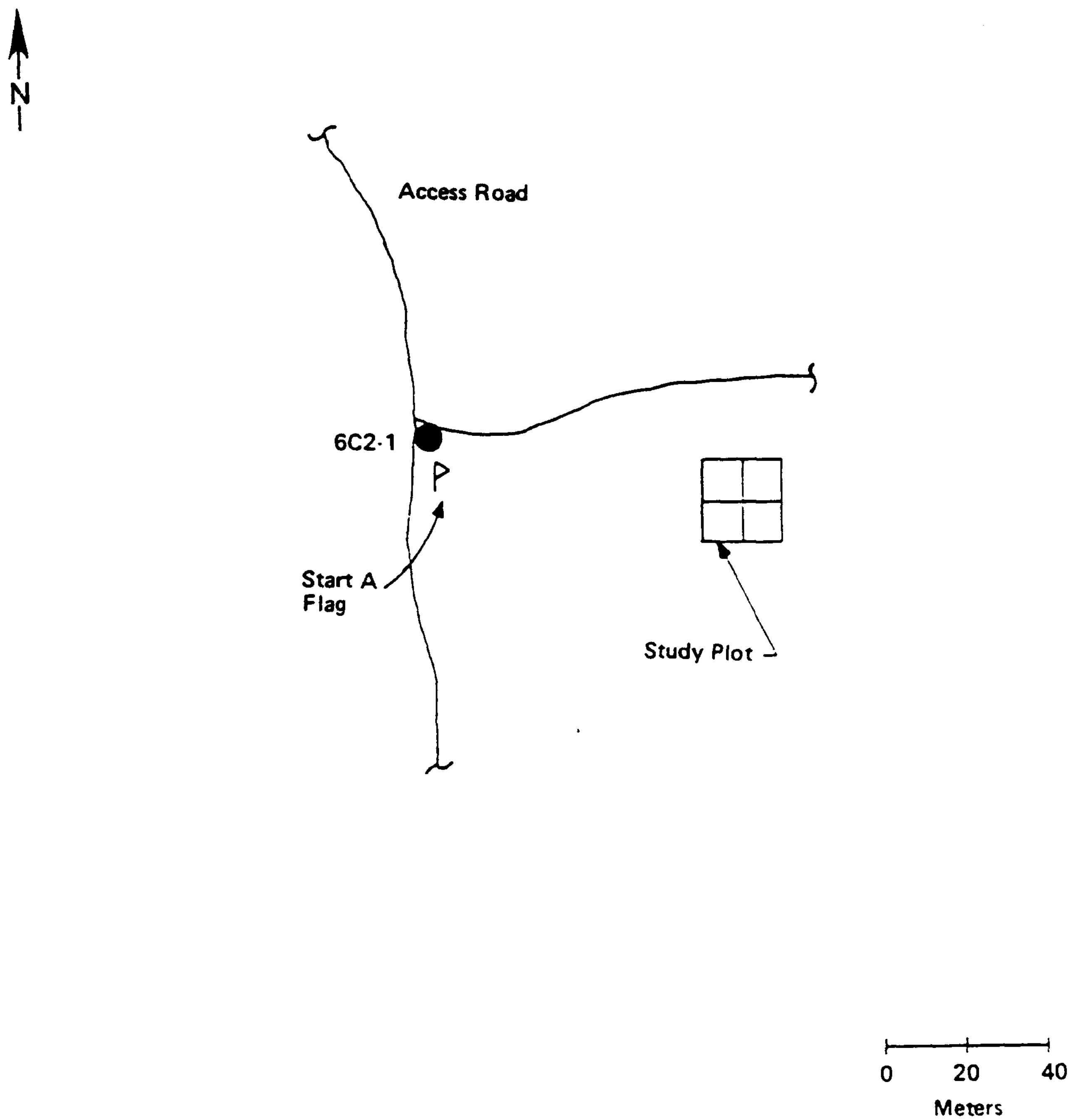


FIGURE F-2. MEASUREMENT POINT AT MERRIMAN TRUCK TRAIL CONTROL; 6C2-1.

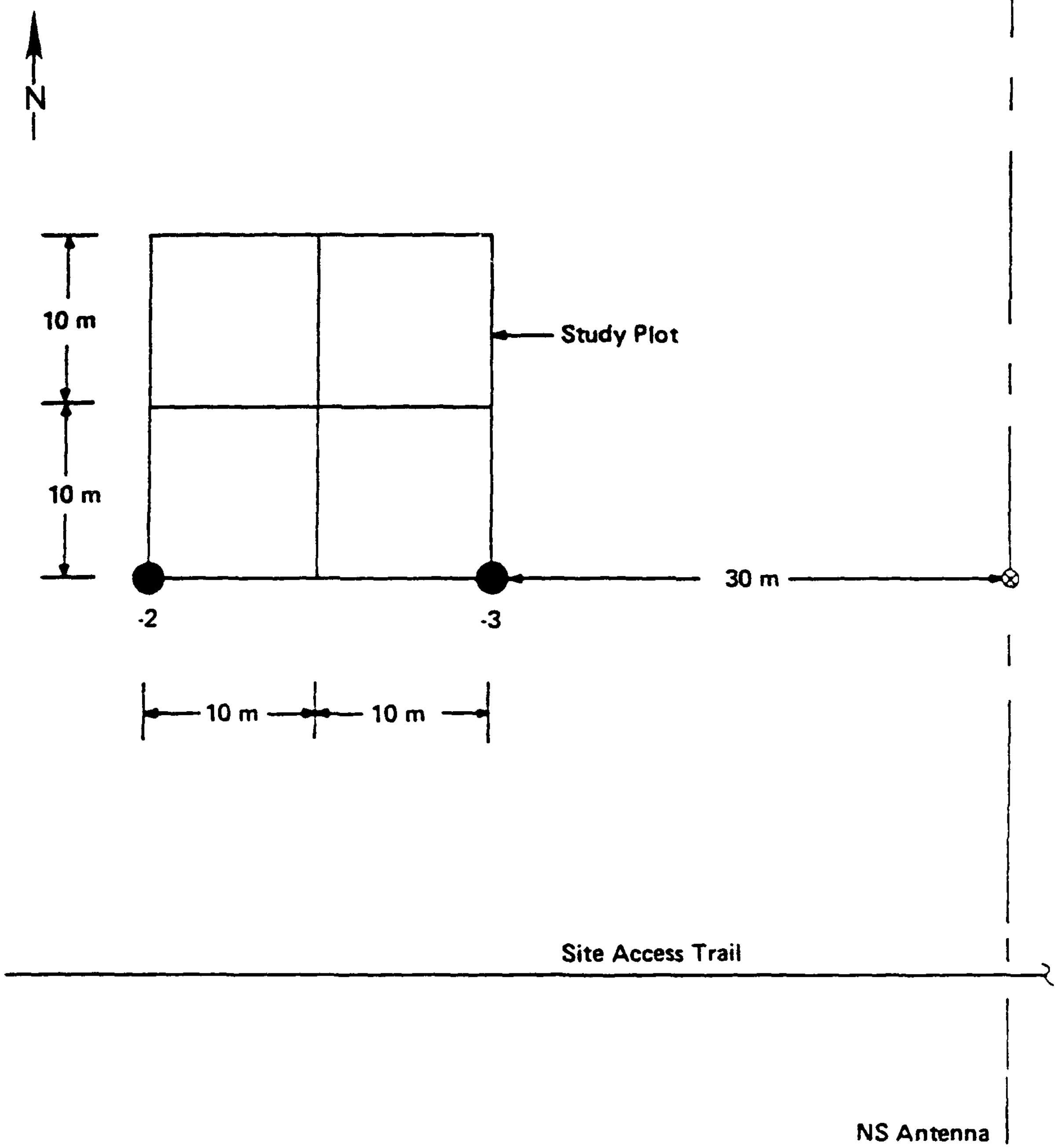


FIGURE F-3. MEASUREMENT POINTS AT LEEMAN'S ROAD; 6 T3-2, 3.

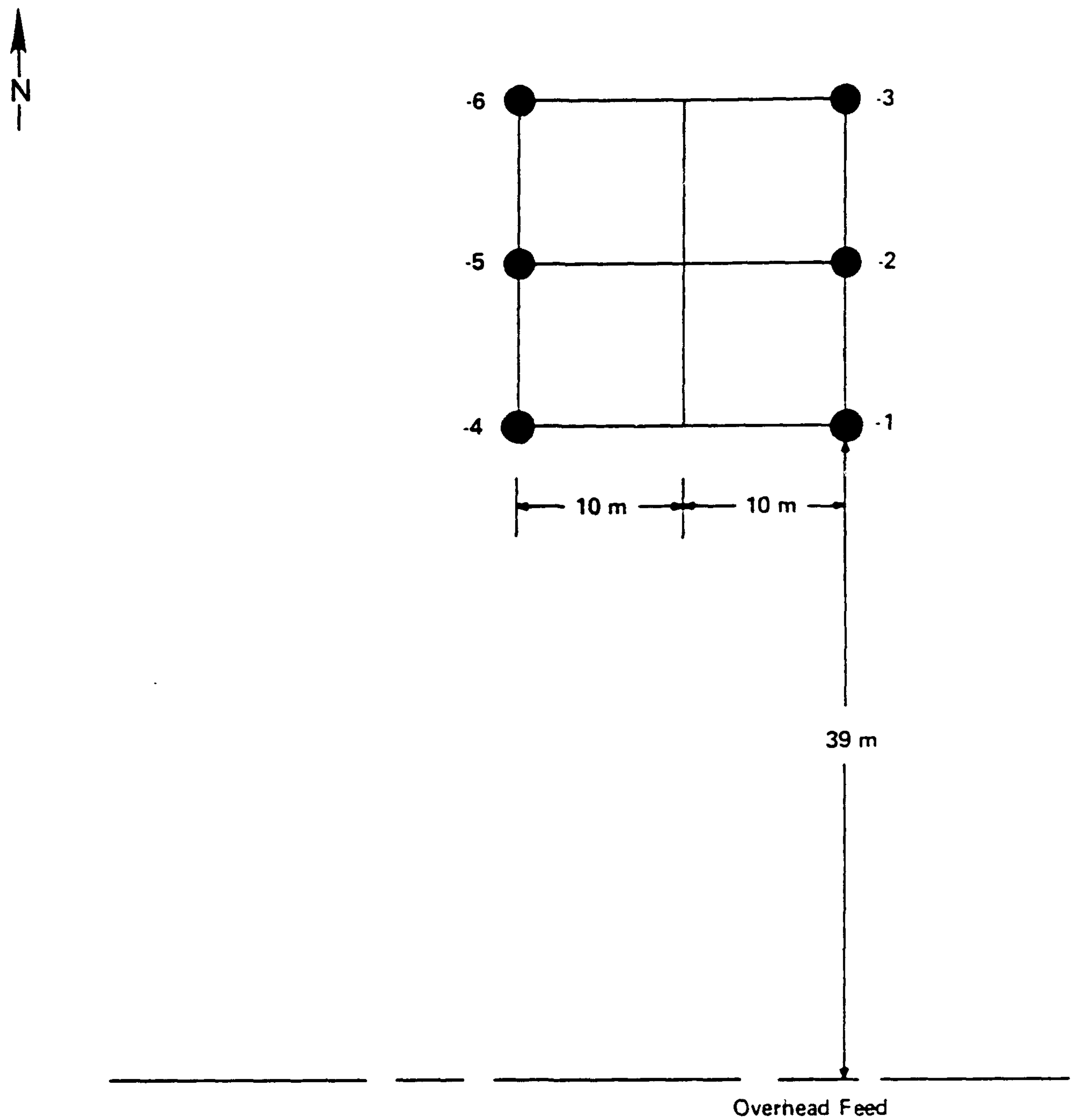


FIGURE F-4. MEASUREMENT POINTS AT WELLS GRADE GROUND; 6T4-1 THROUGH 6.

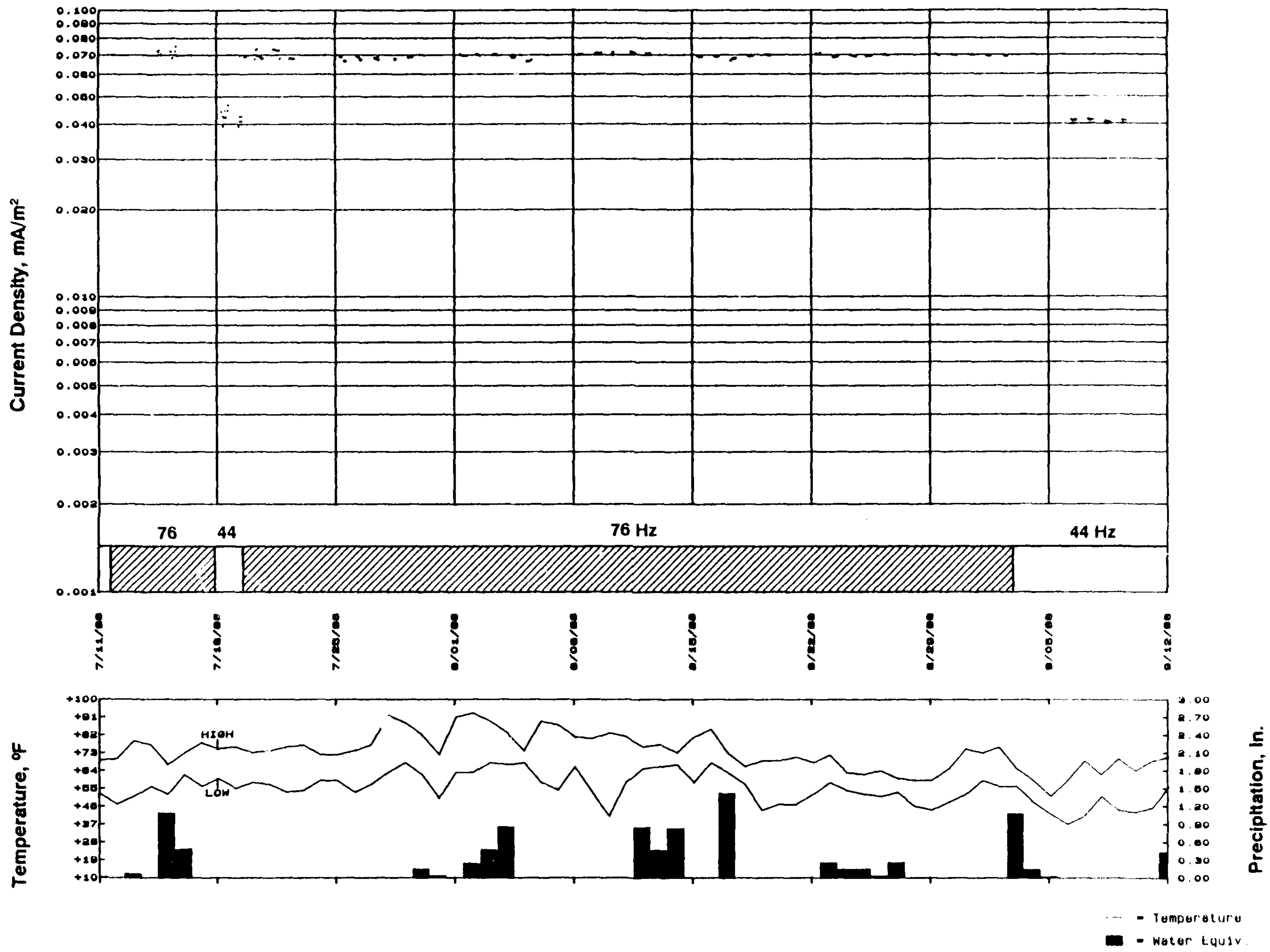


FIGURE F-5. HOURLY EM FIELD MEASUREMENTS FOR CELL #1 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

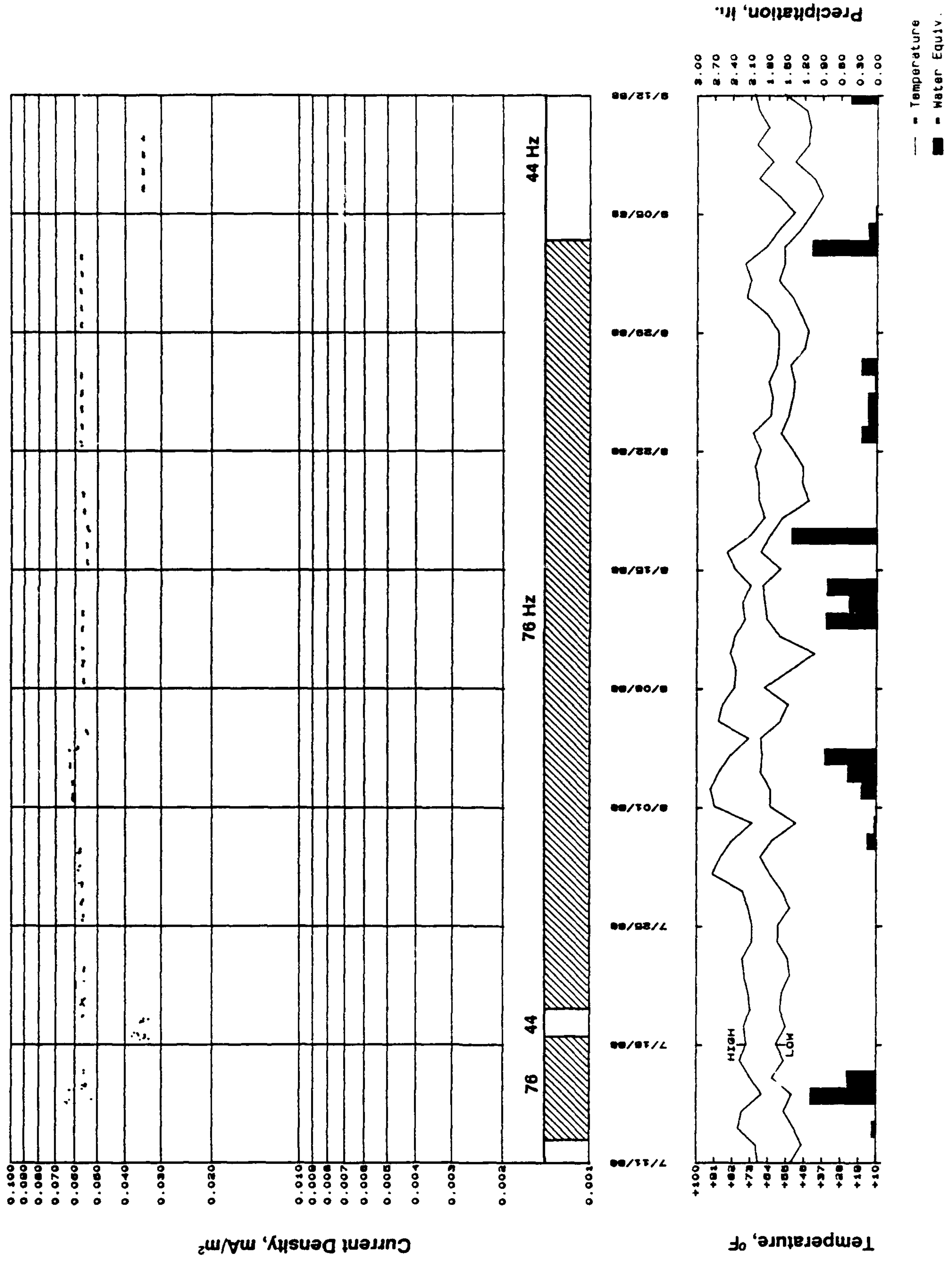


FIGURE F-6. HOURLY EM FIELD MEASUREMENTS FOR CELL #2 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

60297/190

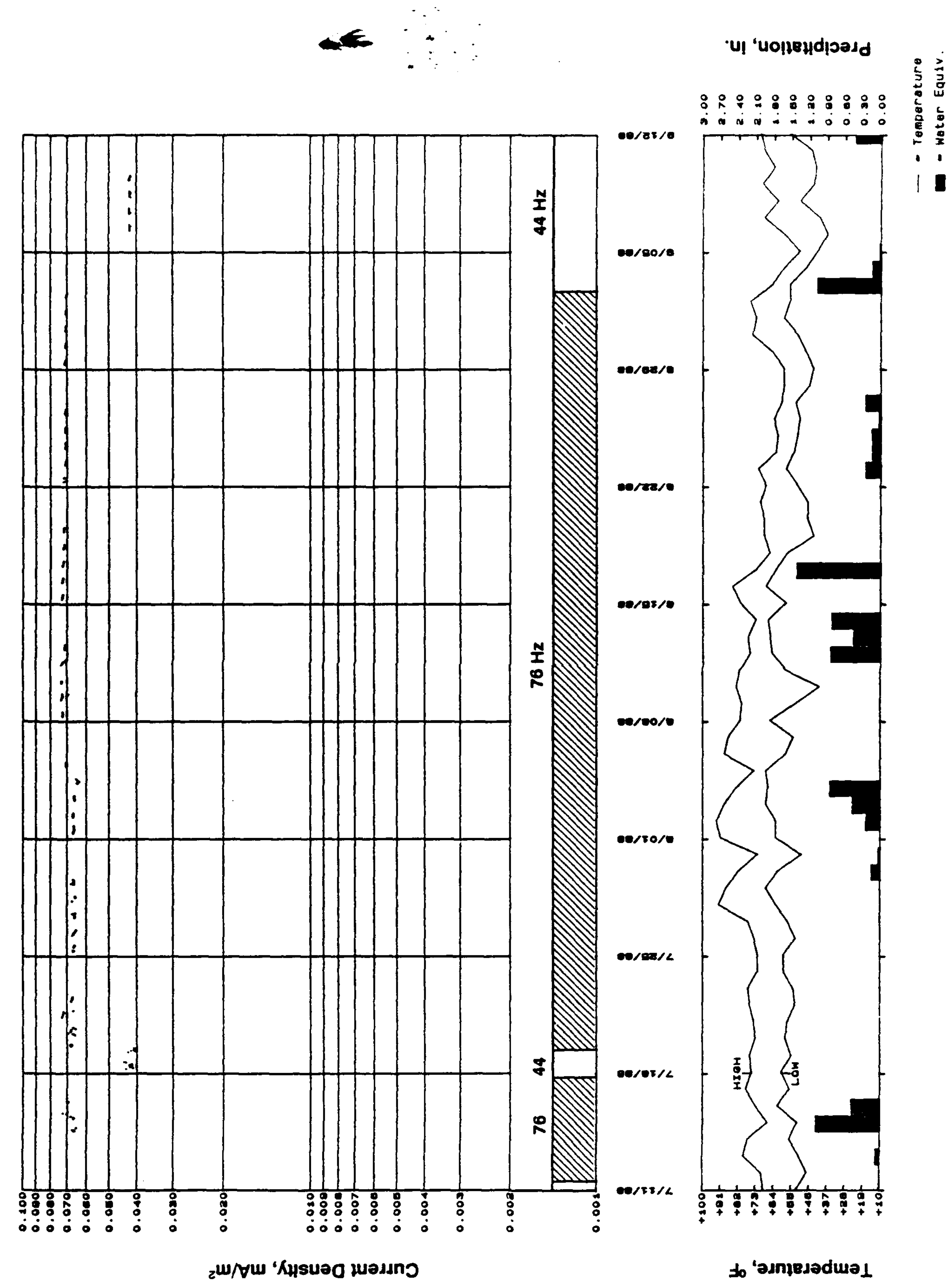


FIGURE F-7. HOURLY EM FIELD MEASUREMENTS FOR CELL #3 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

60297/790

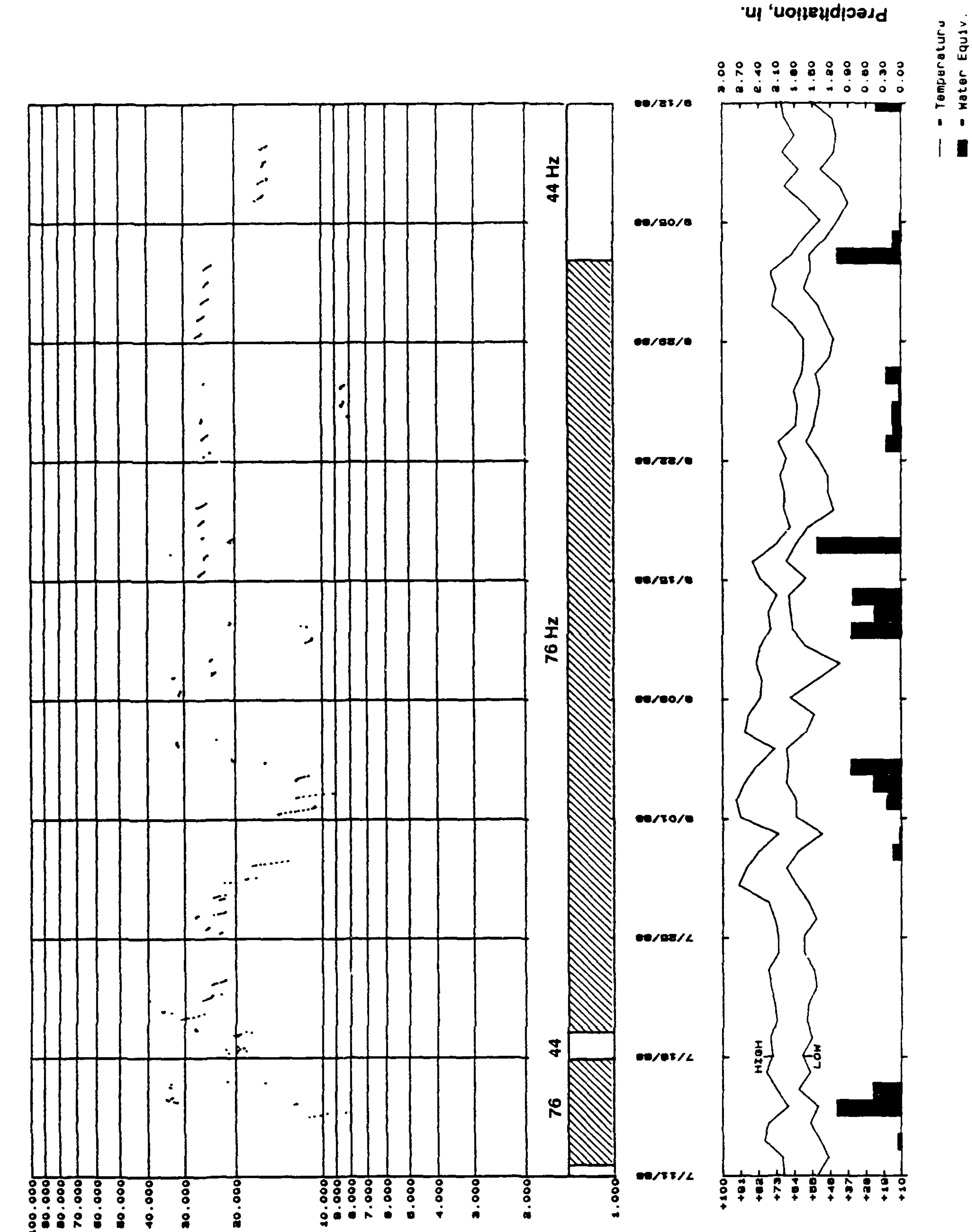


FIGURE F-8. HOURLY EM FIELD MEASUREMENTS FOR CELL #4 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

60297/790

60297/790

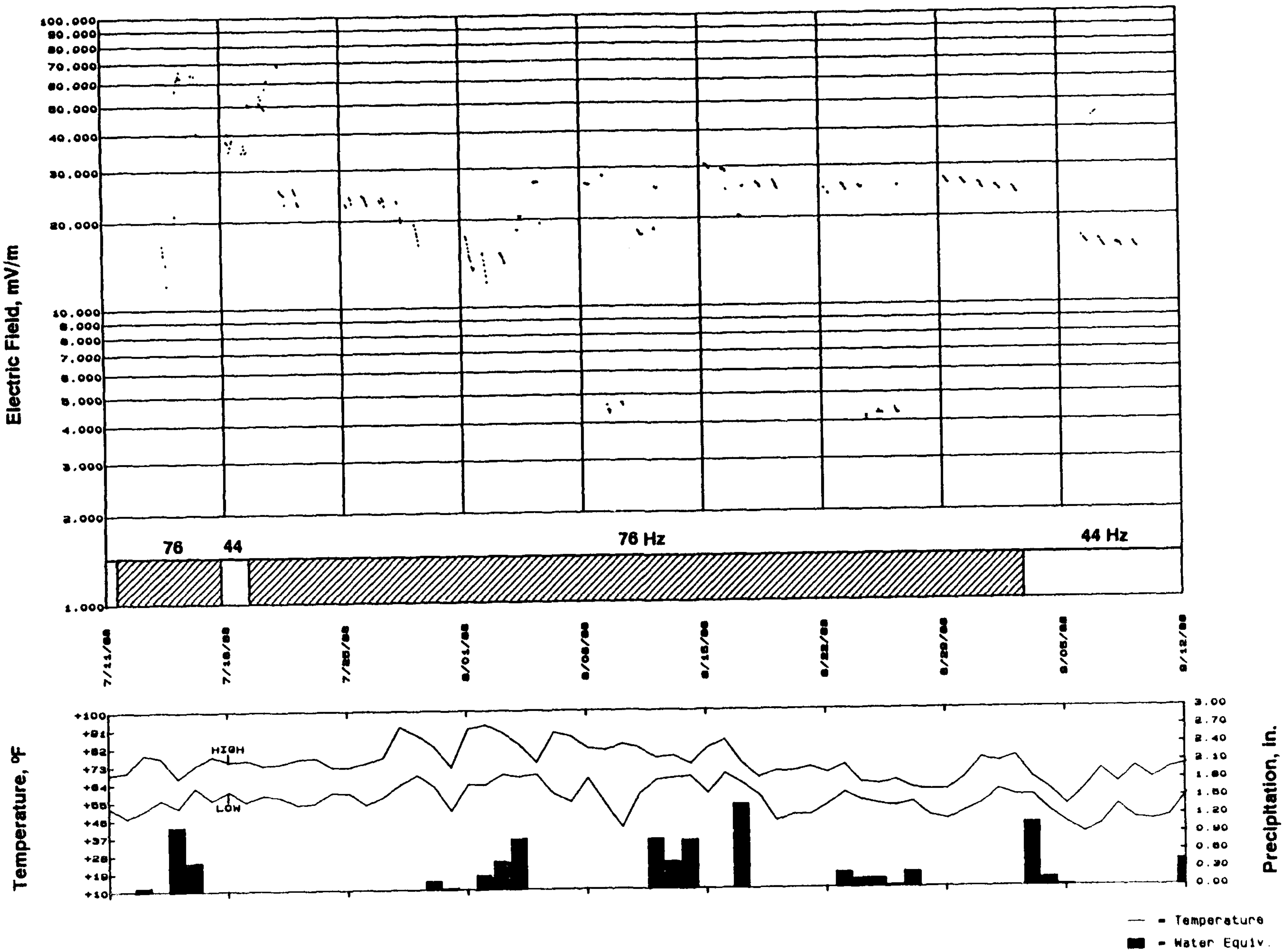


FIGURE F-9. HOURLY EM FIELD MEASUREMENTS FOR CELL #5 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

60297/790

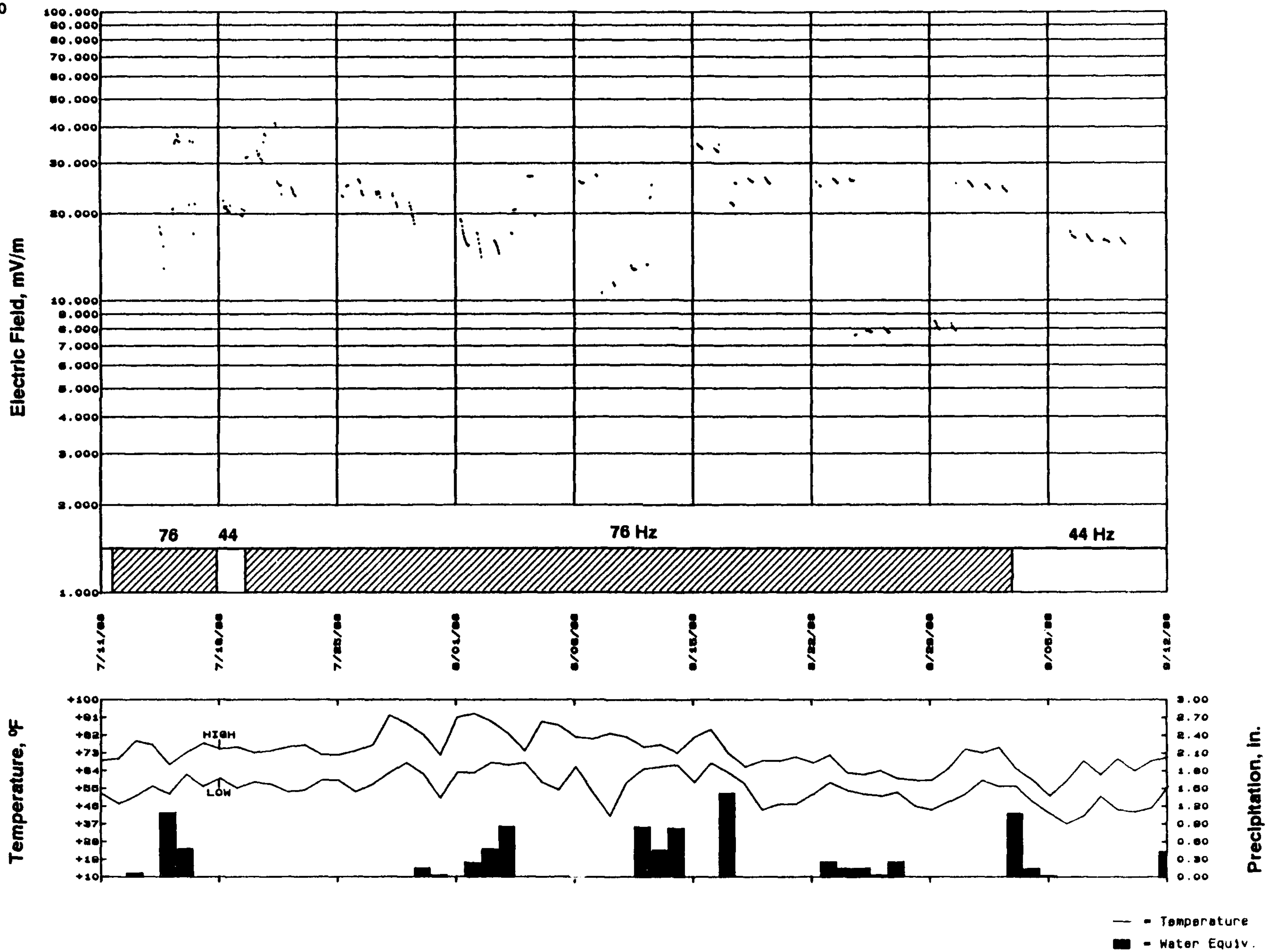


FIGURE F-10. HOURLY EM FIELD MEASUREMENTS FOR CELL #6 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

60297/790

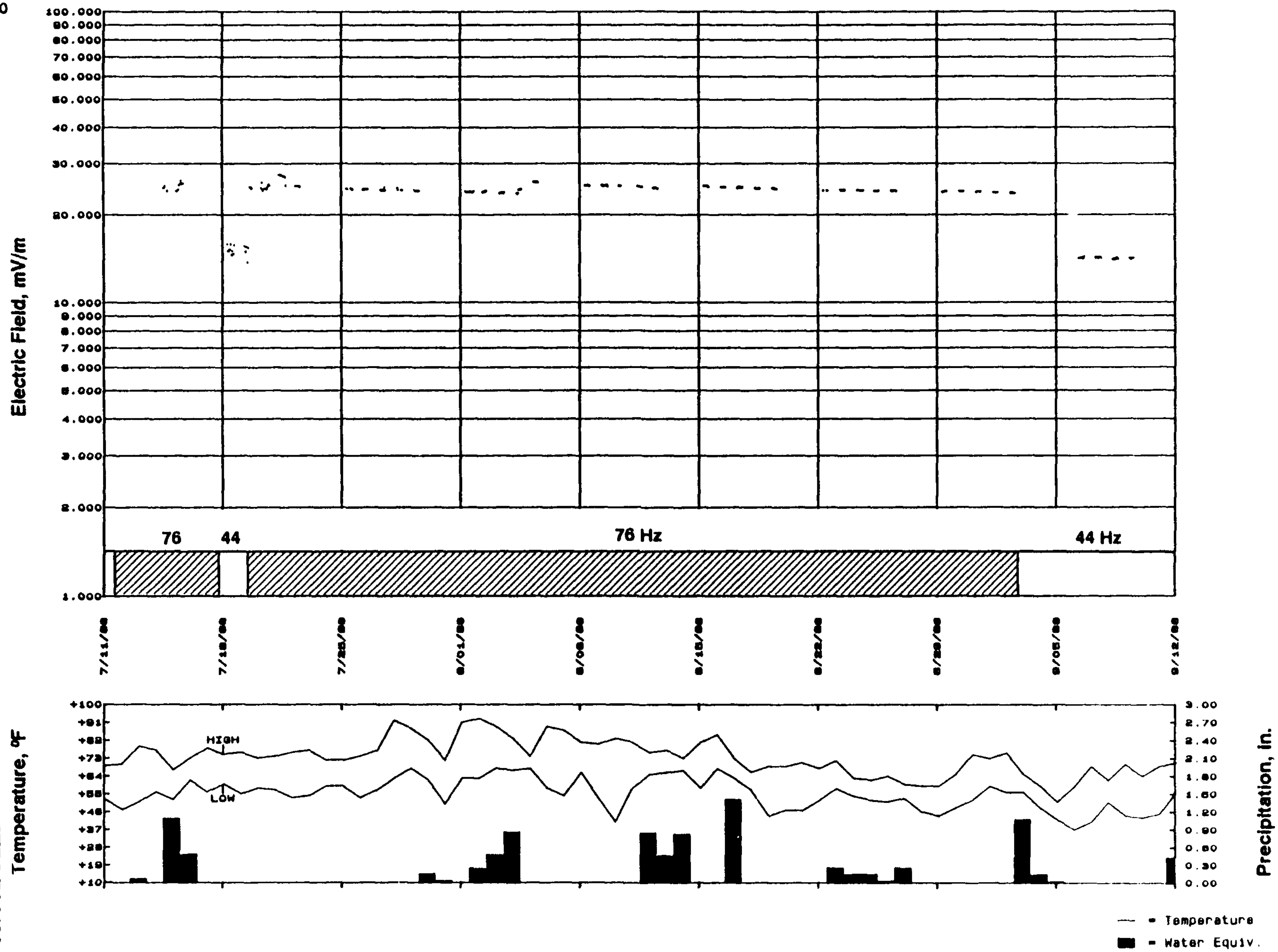


FIGURE F-11. HOURLY EM FIELD MEASUREMENTS FOR PROBE #1 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

60297/790

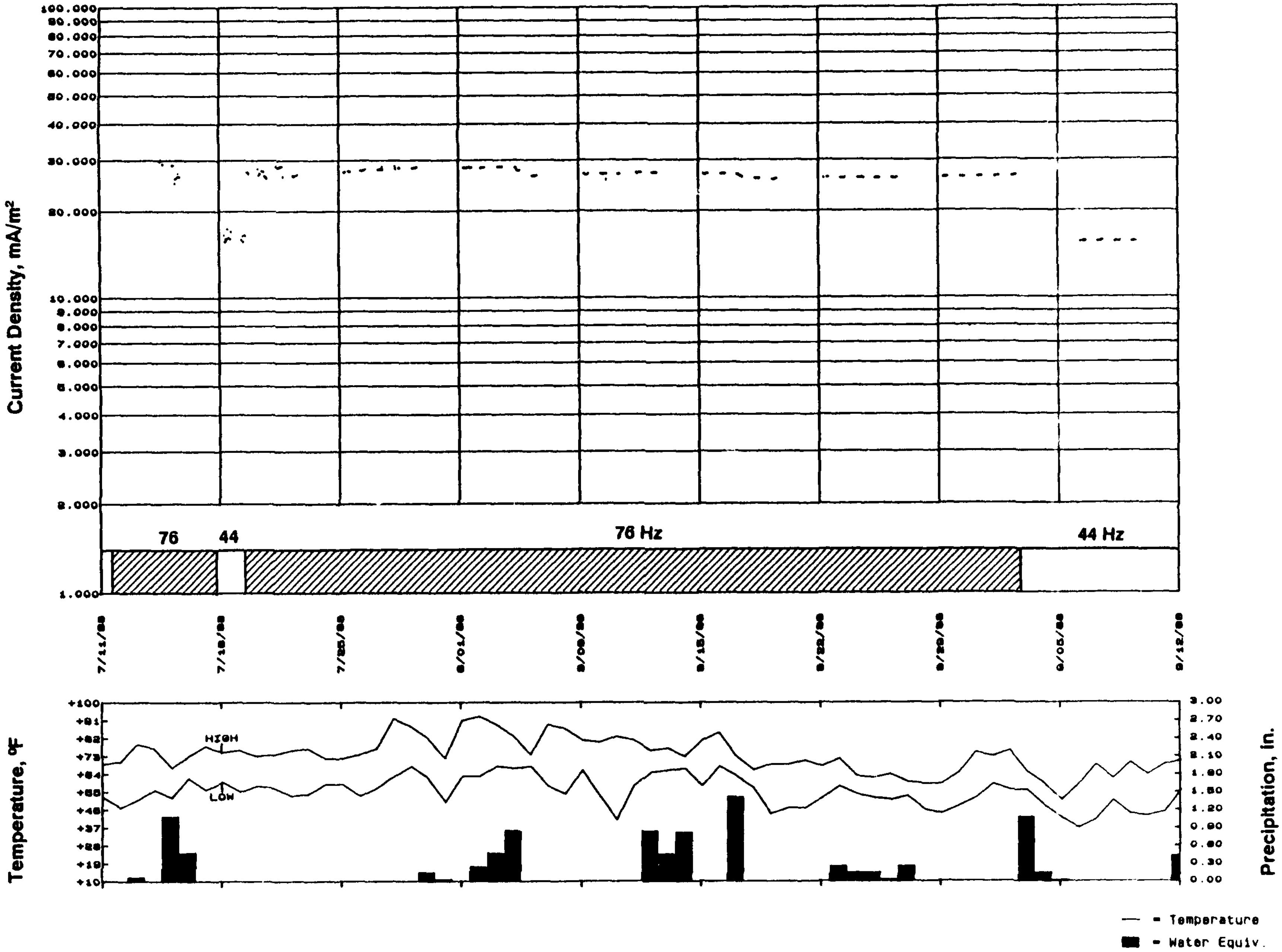


FIGURE F-12. HOURLY EM FIELD MEASUREMENTS FOR PROBE #2 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

60297/790

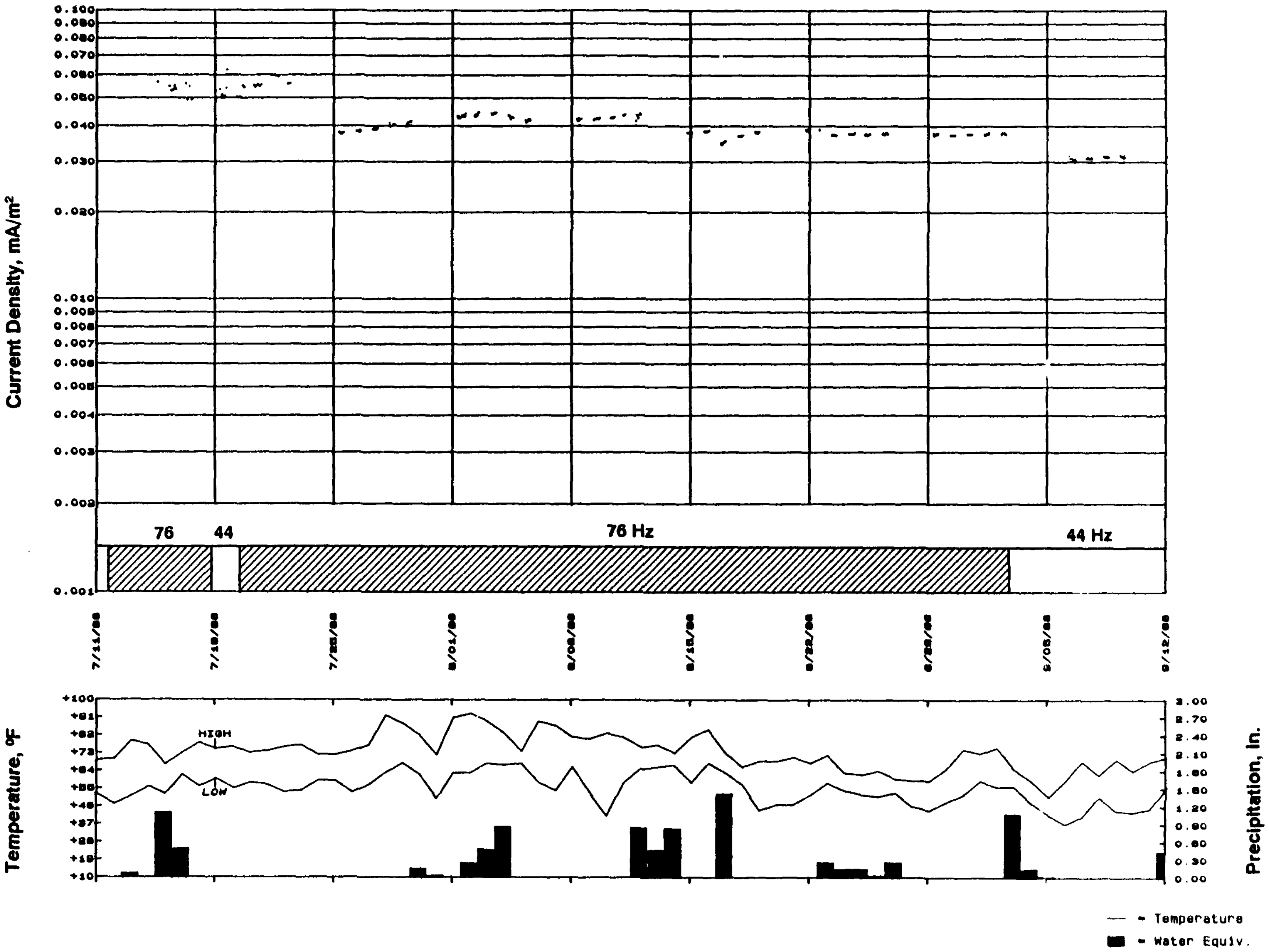


FIGURE F-13. HOURLY EM FIELD MEASUREMENTS FOR CELL #1 AT THE SOIL AMOEBA GROUND STUDY SITE.

60297/790

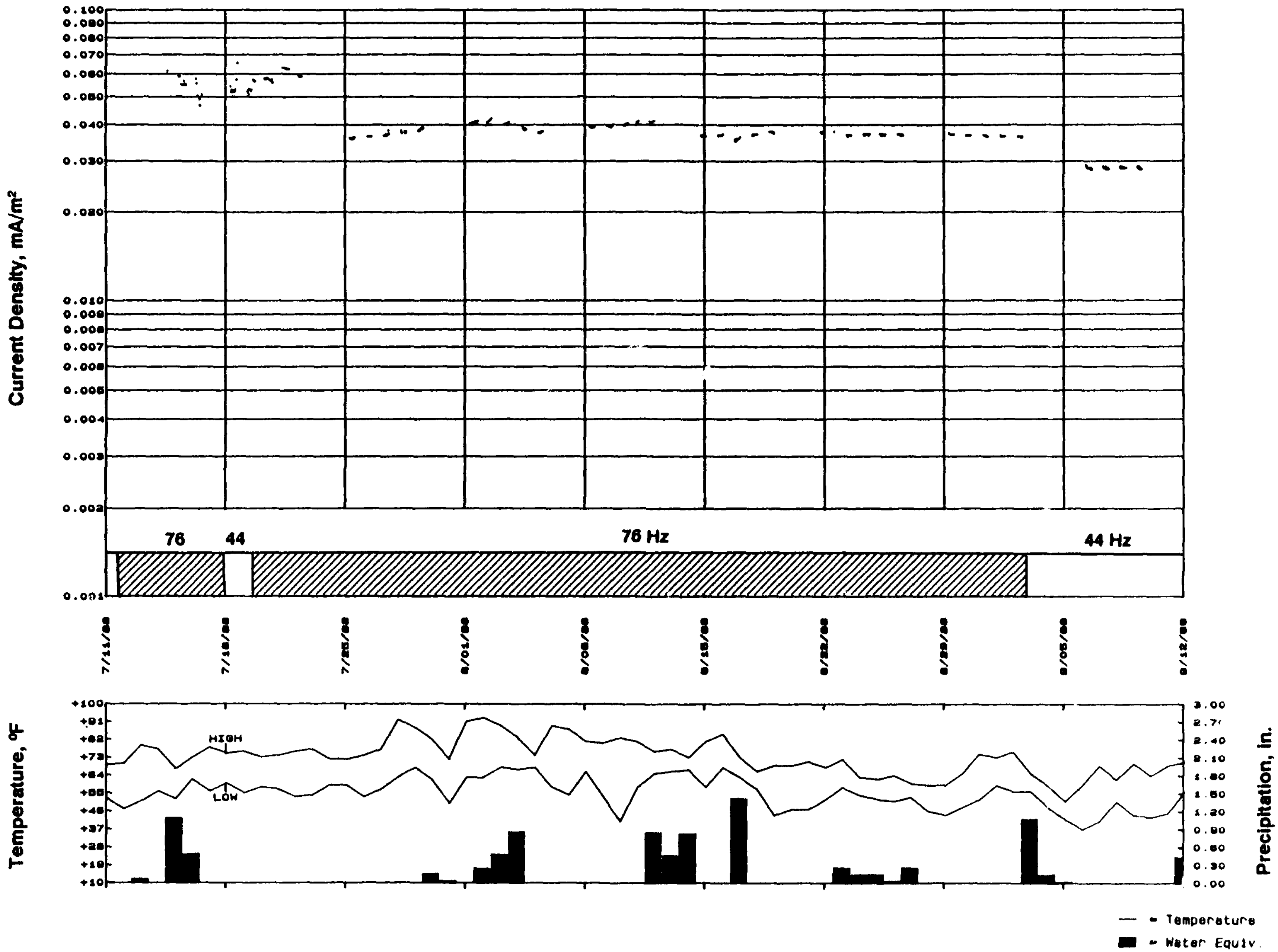


FIGURE F-14. HOURLY EM FIELD MEASUREMENTS FOR CELL #2 AT THE SOIL AMOEBA GROUND STUDY SITE.

60297/790

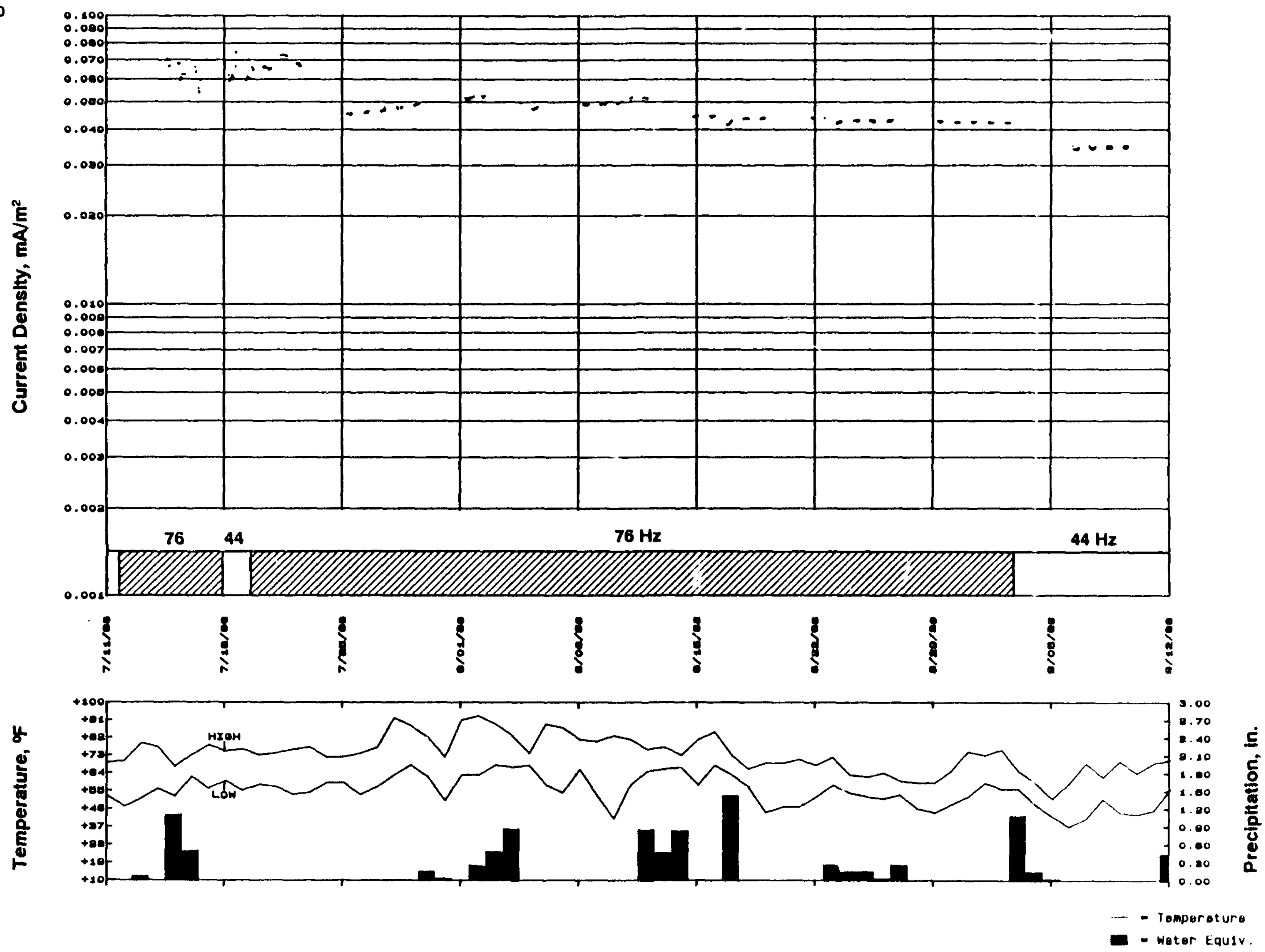


FIGURE F-15. HOURLY EM FIELD MEASUREMENTS FOR CELL #3 AT THE SOIL AMOEBA GROUND STUDY SITE.

60297/790

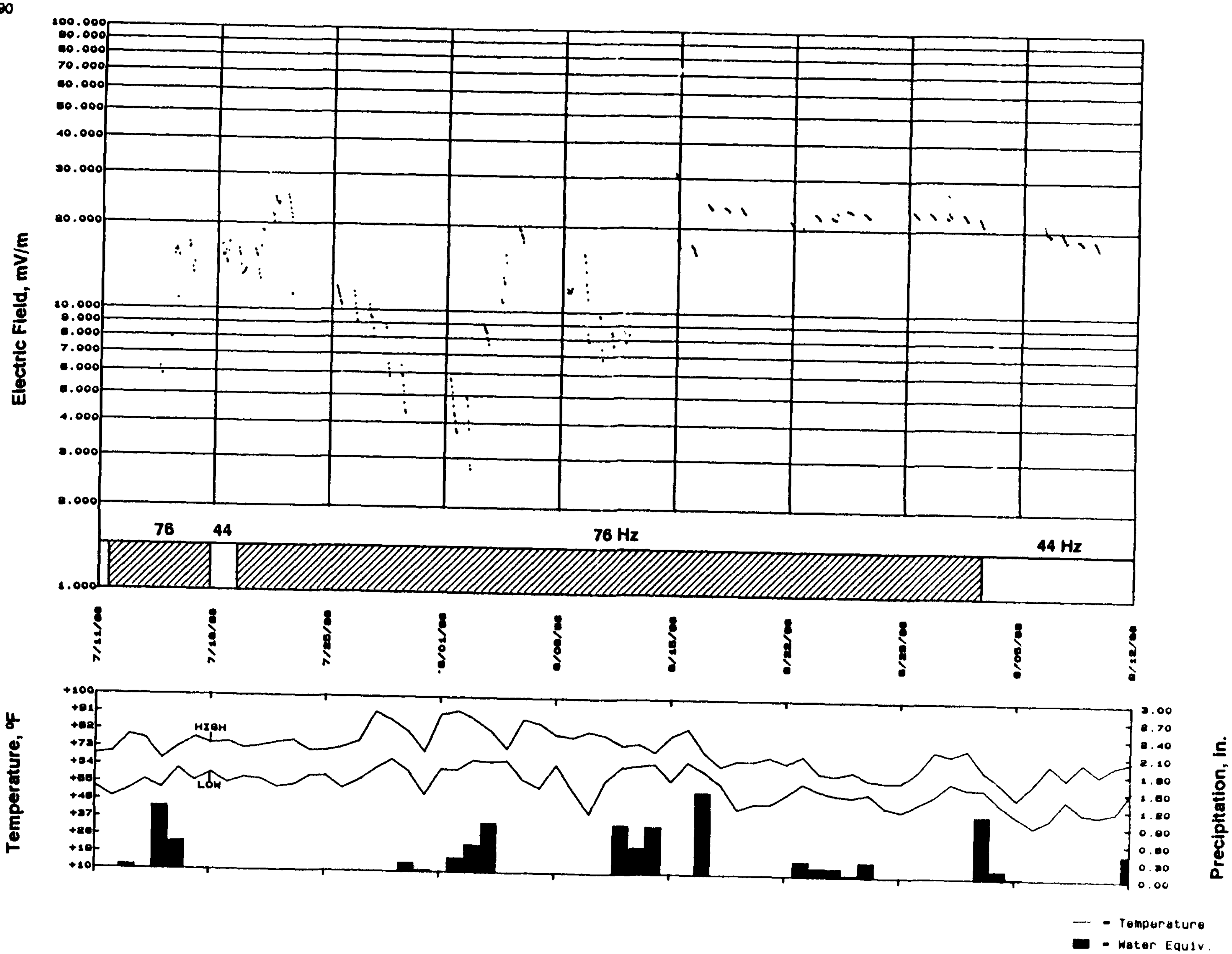


FIGURE F-16. HOURLY EM FIELD MEASUREMENTS FOR CELL #4 AT THE SOIL AMOEBA GROUND STUDY SITE.

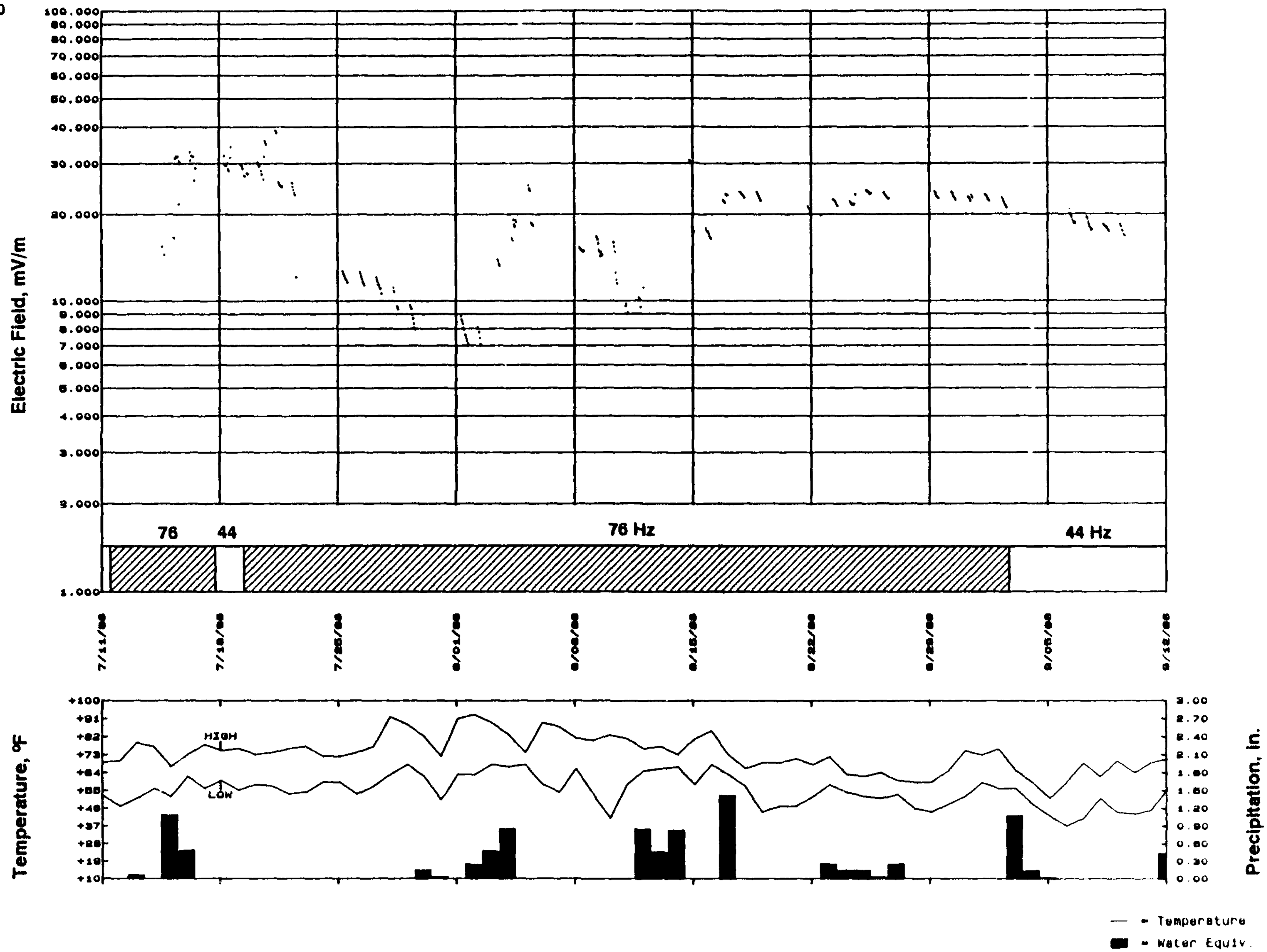


FIGURE F-17. HOURLY EM FIELD MEASUREMENTS FOR CELL #5 AT THE SOIL AMOEBA GROUND STUDY SITE.

60297/790

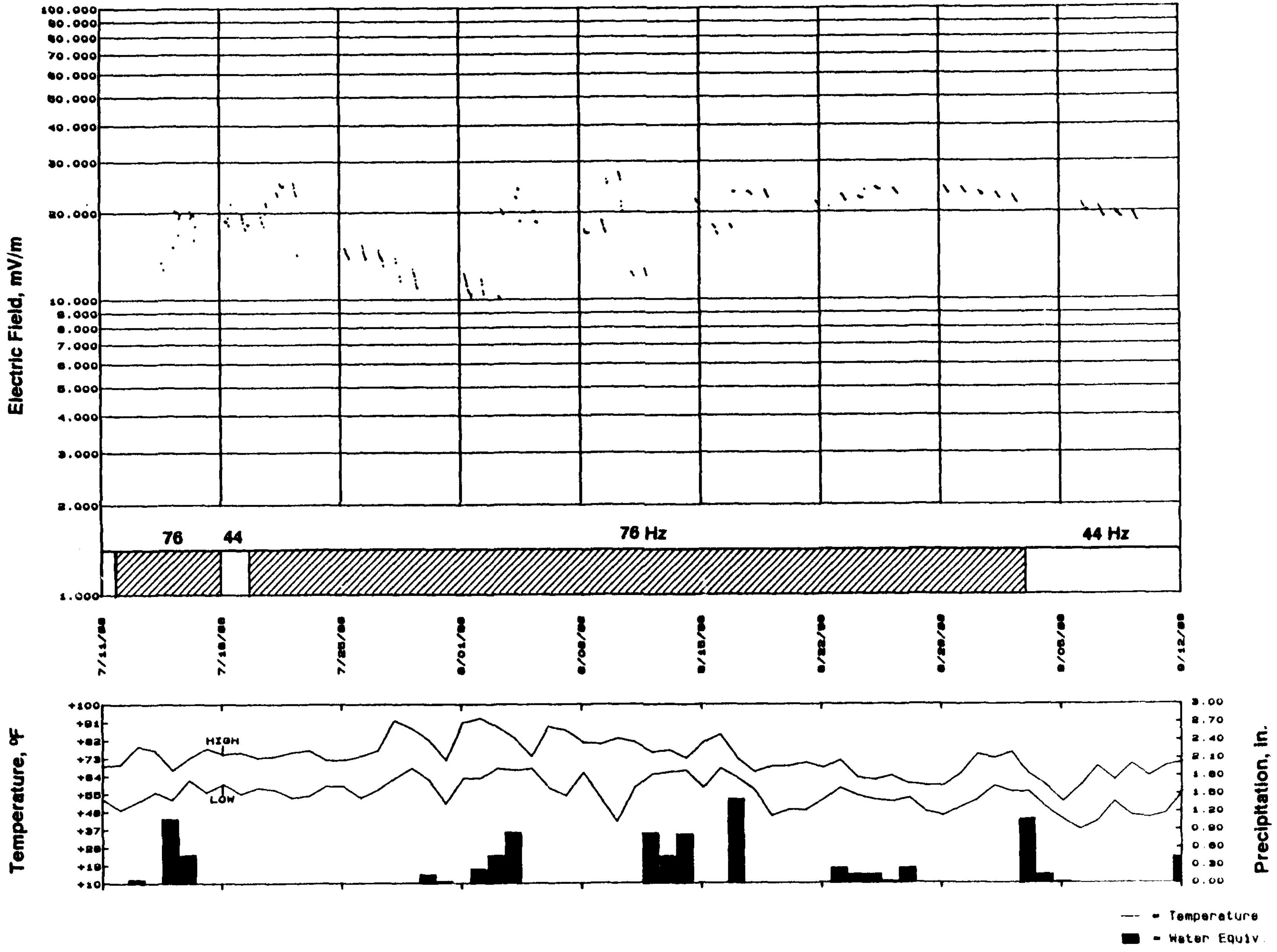


FIGURE F-18. HOURLY EM FIELD MEASUREMENTS FOR CELL #6 AT THE SOIL AMOEBA GROUND STUDY SITE.

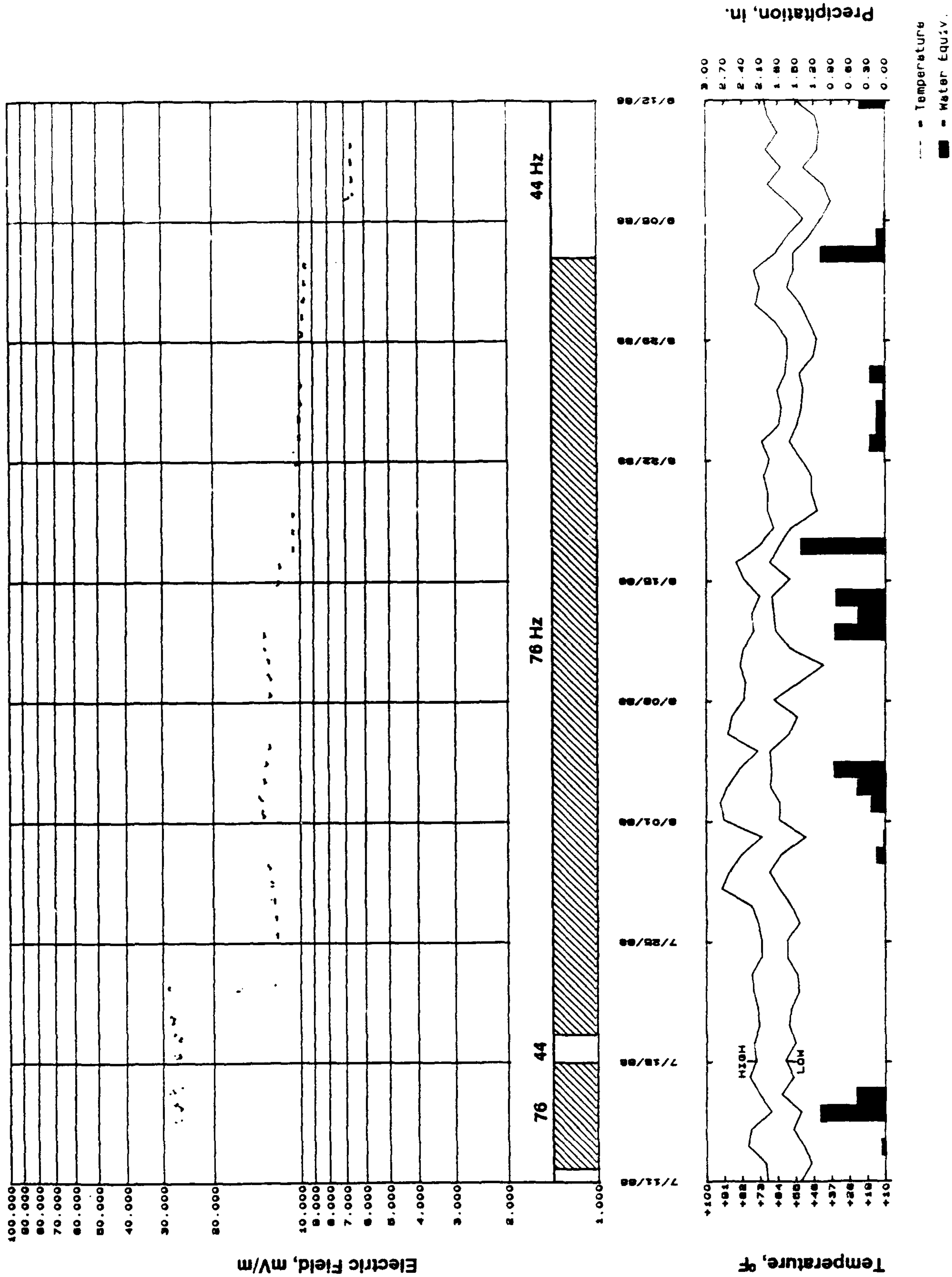


FIGURE F-19. HOURLY EM FIELD MEASUREMENTS FOR PROBE #1 AT THE SOIL AMOEBA GROUND STUDY SITE.

60297/190

60297/790

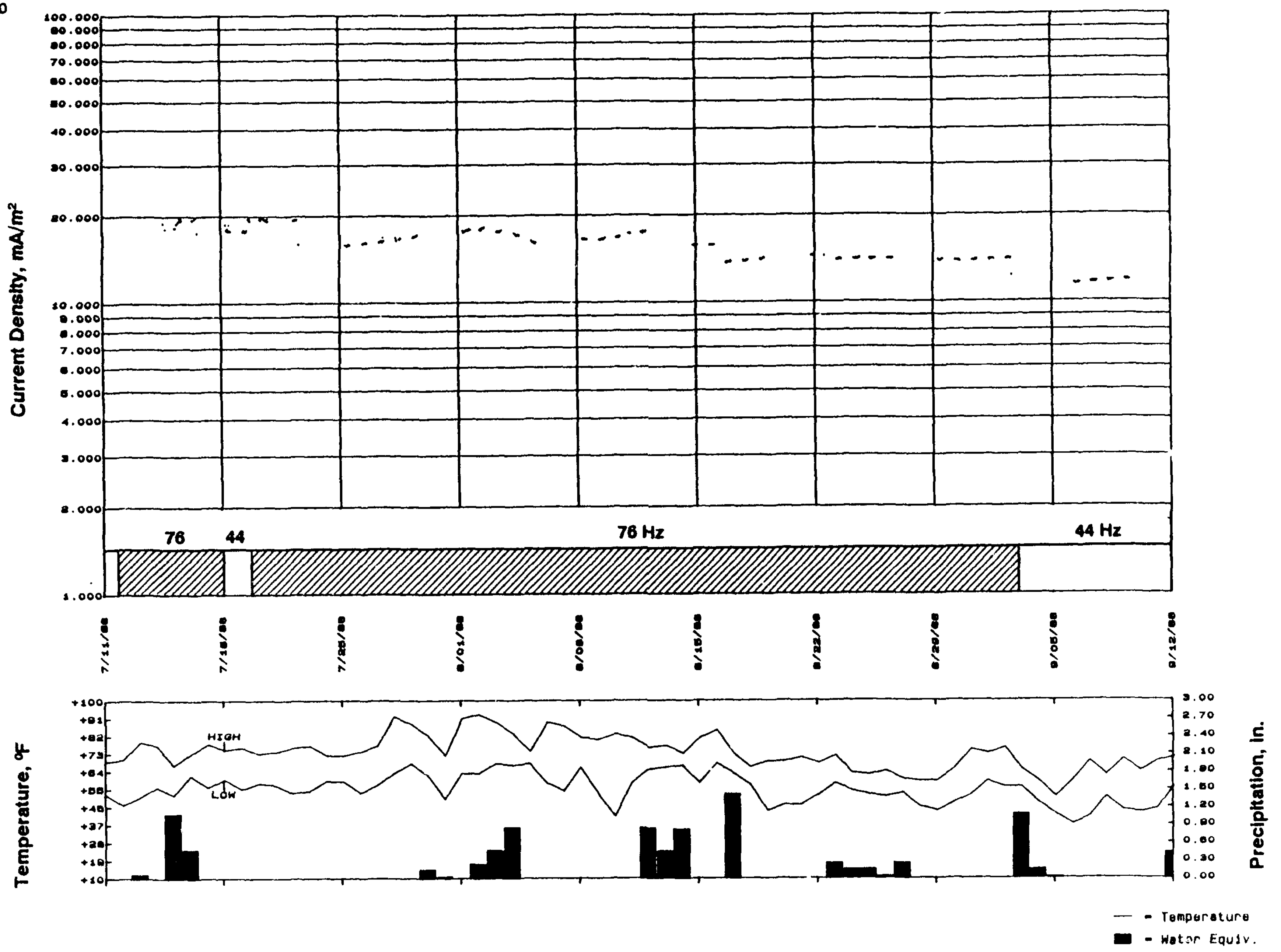


FIGURE F-20. HOURLY EM FIELD MEASUREMENTS FOR PROBE #2 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

TABLE F-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Soil Amoeba Studies

Site No., Meas. Pt.	1983 [a]	1984 [a]	1985 [a]	1986 [b]	1987 [c]	1988 [c]	1989 [d]
6C2-1	<0.001	<	<	<	<	<	<
6T3-2	-	<	<	<	<	<	<
6T3-3	-	-	-	<	<	<	<
6T4-1	-	<	<	<	<	<	<0.001
6T4-2	-	-	-	<	<	<0.001	<
6T4-3	-	-	-	<	<	<	<
6T4-4	-	-	-	<	<	<	<
6T4-5	-	-	-	<	<	<	<
6T4-6	-	-	-	<	<	<	<

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

- = measurement point not established.
< = est. <0.001 V/m based on E-field in ground.

TABLE F-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Soil Amoeba Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]
6C2-1	0.32	0.61	0.194,0.28	0.058	0.256	0.98	1.19
6T3-2	0.087	0.130	0.134	0.078	0.130	0.41	#
6T3-3	-	-	-	0.085	0.125	0.35	#
6T4-1	-	0.48,0.52	0.40	0.072	0.32	0.18	0.35
6T4-2	-	-	-	0.046	0.162	0.145	0.30
6T4-3	-	-	-	0.065	0.082	0.24	0.34
6T4-4	-	-	-	0.037	0.24	0.27	0.23
6T4-5	-	-	-	0.053	0.182	0.18	0.33
6T4-6	-	-	-	0.098	0.084	0.33	0.34

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

- = measurement point not established.
= measurement not possible.

TABLE F-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Amoeba Studies

Site No., Meas. Pt.	1983 [a]	1984 [a]	1985 [a]	1986 [b]	1987 [c]	1988 [c]	1989 [d]
6C2-1	0.004	0.008	0.001,0.003	0.002	0.003	0.011	0.009
6T3-2	-	0.002	0.003	0.013	0.033	0.103	#
6T3-3	-	-	-	0.020	0.023	0.065	#
6T4-1	-	0.005,0.007	0.007	0.005	0.006	0.019	0.011
6T4-2	-	-	-	0.005	0.006	0.016	0.009
6T4-3	-	-	-	0.004	0.005	0.014	0.008
6T4-4	-	-	-	0.002	0.006	0.018	0.010
6T4-5	-	-	-	0.003	0.006	0.017	0.009
6T4-6	-	-	-	0.005	0.005	0.015	0.009

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

- = measurement point not established.
= measurement not possible.

TABLE F-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Soil Amoeba Studies

SITE NO., MEAS.PT.	1986 NS 4 amps	1986 NEW 6 amps	1986 SEW 6 amps	1986 SEW 10 amps (EX)	1987 NS 15 amps	1987 EW 15 amps	1988 NS 75 amps	1988 EW 75 amps	1989 B 150 amps
6C2-1	<	<	<	*	<	<	<	<	<
6T3-2	<	<	<	*	0.005	<	0.028	<	0.061
6T3-3	<	<	<	*	0.005	<	0.027	<	0.058
6T4-1	<	<	<	*	0.020	<	0.047	<	0.036
6T4-2	<	<	<	*	0.007	<	0.022	<0.001	0.030
6T4-3	<	<	<	*	0.004	<	0.030	<	0.045
6T4-4	<	<	<	*	0.014	<	0.035	<	0.028
6T4-5	<	<	<	*	0.007	<	0.036	<0.001	0.047
6T4-6	<	<	<	*	0.004	<	0.043	<	0.050

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

< = est. <0.001 V/m based on E-field in ground.
* = data cannot be extrapolated.

TABLE F-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Soil Amoeba Studies

	1986				1987		1988		1989
SITE NO., MEAS.PT.	NS 4 amps	NEW 6 amps	SEW 6 amps	SEW 10 amps (EX)	NS 15 amps	EW 15 amps	NS 75 amps	EW 75 amps	B 150 amps
6C2-1	0.028	0.010	0.011	0.018	0.068	0.028	0.36	0.140	1.37
6T3-2	1.45	0.046	0.040	0.067	5.9	0.110	25	0.46	54
6T3-3	1.34	0.041	0.030	0.050	5.4	0.087	21	0.47	47
6T4-1	1.73	0.059	0.007	0.012	18.9	0.056	25	0.22	30
6T4-2	0.72	0.023	0.009	0.015	8.5	0.038	12.4	0.150	35
6T4-3	1.14	0.035	0.018	0.030	4.3	0.031	21	0.191	49
6T4-4	1.31	0.042	0.006	0.010	12.8	0.040	21	0.174	18.4
6T4-5	0.78	0.027	0.012	0.020	10.2	0.045	15.5	0.194	33
6T4-6	1.27	0.040	0.015	0.025	4.4	0.034	26	0.22	50

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = *southern EW antenna element.*
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

TABLE F-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Amoeba Studies

	1986				1987		1988		1989
SITE NO., MEAS. PT.	NS 4 amps	NEW 6 amps	SEW 6 amps	SEW 10 amps (EX)	NS 15 amps	EW 15 amps	NS 75 amps	EW 75 amps	B 150 amps
6C2-1	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.002	0.001	0.004
6T3-2	0.28	0.009	0.001	0.002	1.03	0.004	4.9	0.011	10.1
6T3-3	0.170	0.006	0.001	0.002	0.64	0.003	3.1	0.007	6.3
6T4-1	0.100	0.003	0.001	0.002	0.35	0.001	1.82	0.007	4.1
6T4-2	0.082	0.003	0.001	0.002	0.29	0.001	1.50	0.006	3.3
6T4-3	0.071	0.002	<0.001	*	0.26	0.001	1.30	0.005	2.9
6T4-4	0.090	0.003	0.001	0.002	0.38	0.001	1.64	0.006	3.8
6T4-5	0.078	0.002	<0.001	*	0.27	<0.001	1.41	0.006	3.4
6T4-6	0.067	0.002	<0.001	*	0.24	0.001	1.22	0.005	2.7

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

* = data cannot be extrapolated.

APPENDIX G

BIRD SPECIES AND COMMUNITIES STUDIES

BIRD SPECIES AND COMMUNITIES STUDIES

During August 1989, IITRI field crews made ELF electromagnetic (EM) field measurements at 22 measurement points at five treatment and five control transects for the bird species and communities studies in Wisconsin. Measurements at 24 points at the five treatment and five control transects in Michigan were conducted during September. The study transects and the measurement points within those transects were unchanged from 1988. Four treatment transects in Wisconsin (10T6, 10T7, 10T9, and 10T10) were given special attention and examined in more detail; measurements were taken along these transects at their start and finish, and between the eight subsegments at each "X" flag. These data were taken to determine typical EM field variability along study transects. (Similar measurements were made at transects 10C7 and 10T8 in 1988.)

The positions of the 10 Wisconsin transects and 10 Michigan transects relative to the NRTF-Clam Lake and the NRTF-Republic, respectively, are shown on the composite maps in Figures G-1 and G-2. The transect numbers listed on the map are those used by IITRI. Table G-1 provides a cross-reference of IITRI transect numbers, investigator transect names, and township, range, and section numbers for the transects in both Wisconsin and Michigan.

The bird species and communities studies monitor migrating bird population using a census technique that involves variable-width transects. The study involves monitoring the total population of migrating birds in an area both as a whole and as individual species. The electric and magnetic fields in the air are considered the most important EM factors influencing migrating birds; however, the electric field in the earth may also have an influence.

Wisconsin Measurements

Historical Measurements

EM field measurements for Wisconsin for 1989 and previous years are found in Tables G-2, G-3, and G-4, which present 76 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. There were no significant changes in the 76 Hz EM field intensities in Wisconsin in 1989. Some year-to-year variations in the longitudinal electric field intensities are indicated; these were likely caused by annual and seasonal variations in soil conductivity.

Measurement of 60 Hz ambient EM fields had not been possible at the NRTF-Clam Lake since mid-1985 because of its full-time operating status and modulated signal. In 1989, special testing procedures at the NRTF-Clam Lake allowed for 60 Hz measurements to again be taken at the study sites. 60 Hz measurement data from 1984, early 1985, and 1989 are given in Table G-5.

EM Gradients Perpendicular to Antenna

Measurements made at regular intervals on a line perpendicular to the NS antenna of the NRTF-Clam Lake and to study transect 10T8 were made in 1988; these data are shown in Table G-6. The data define typical gradients of 76 Hz longitudinal electric field intensity and magnetic flux density across the study transect. Graphs and a discussion of these data appear in Section 4.4.3 of this report.

EM Field Variations Along Study Transects

Data for electric and magnetic fields along transects 10C7, 10T7, 10T8, 10T9, and 10T10 are shown in Table G-7. Measurements were taken at the start and finish of each transect as well as between transect subsegments at each "X" flag. Table G-7 also includes data from applicable historical measurement locations. The EM field intensities along these transects are presented graphically and discussed in Section 4.4.3.

Michigan Measurements

EM field measurements for Michigan for 1989 and previous years are found in Tables G-8 through G-13. Tables G-8, G-9, and G-10 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables G-11, G-12, and G-13 present 76 Hz data for these fields at the corresponding operating currents of the NRTF-Republic for each year.

Ambient 60 Hz EM field intensities could not be measured at four treatment sites in 1989 because of modulated signal operation of the NRTF-Republic. The 60 Hz EM field intensities that were measured at Michigan transects, however, are consistent with those measured in previous years.

The 1989, 76 Hz measurements were made with 150 ampere antenna currents, the predominant operating current of the NRTF-Republic since 4 May 1989. The EM exposures at the study sites for the period prior to 4 May can be estimated either by using the 75 ampere antenna current measurement data from 1988 or by using one-half the value of 1989, 150 ampere data.

The EM field variability along Michigan transects has not yet been measured because of time and weather constraints. IITRI plans to randomly select and measure a control and a treatment transect in 1990, as was done for Wisconsin transects, in order to determine the EM variability along the transects.

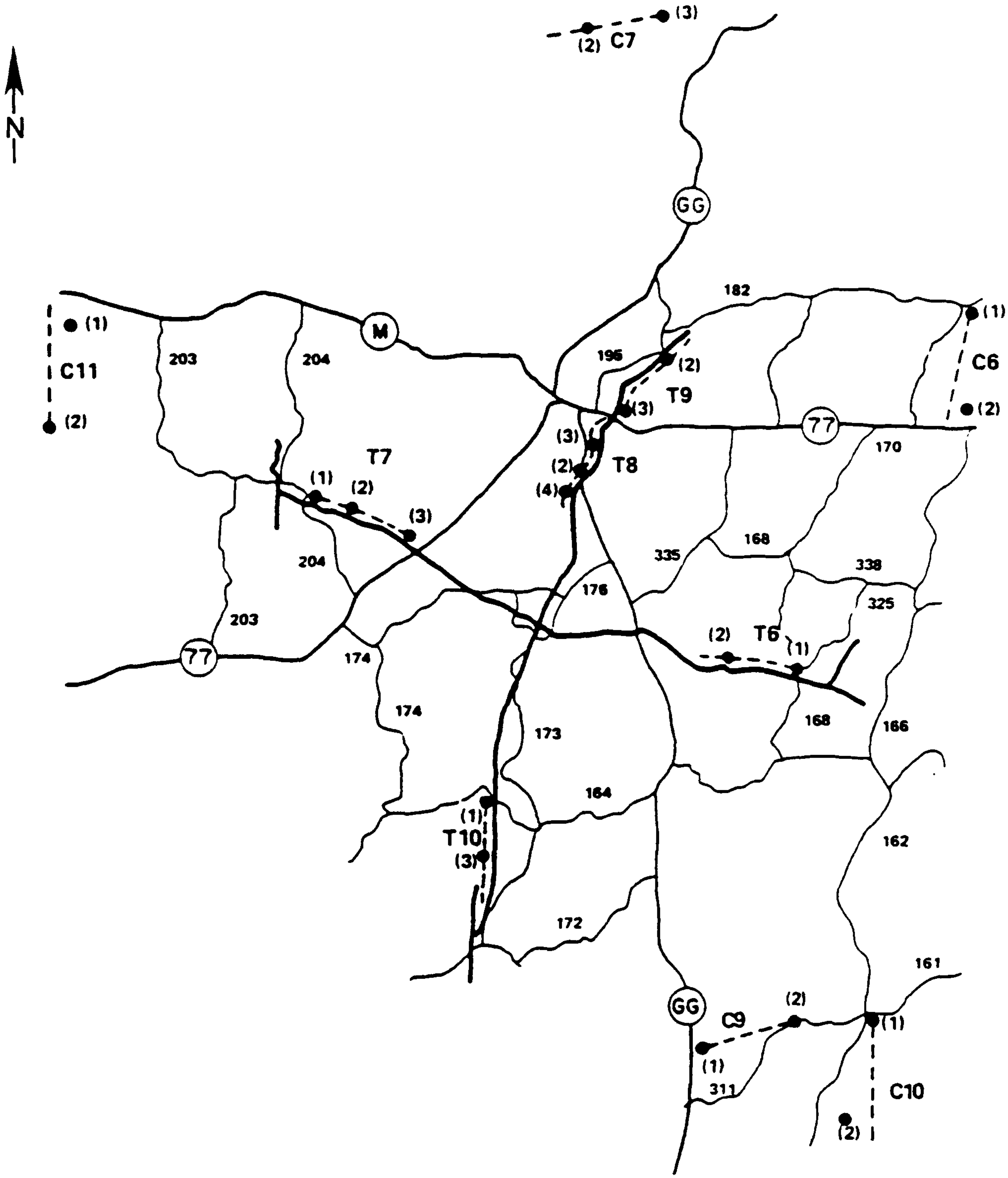


FIGURE G-1. POSITIONS OF BIRD SPECIES AND COMMUNITIES STUDY TRANSECTS RELATIVE TO NRTF-CLAM LAKE ANTENNA ELEMENTS.

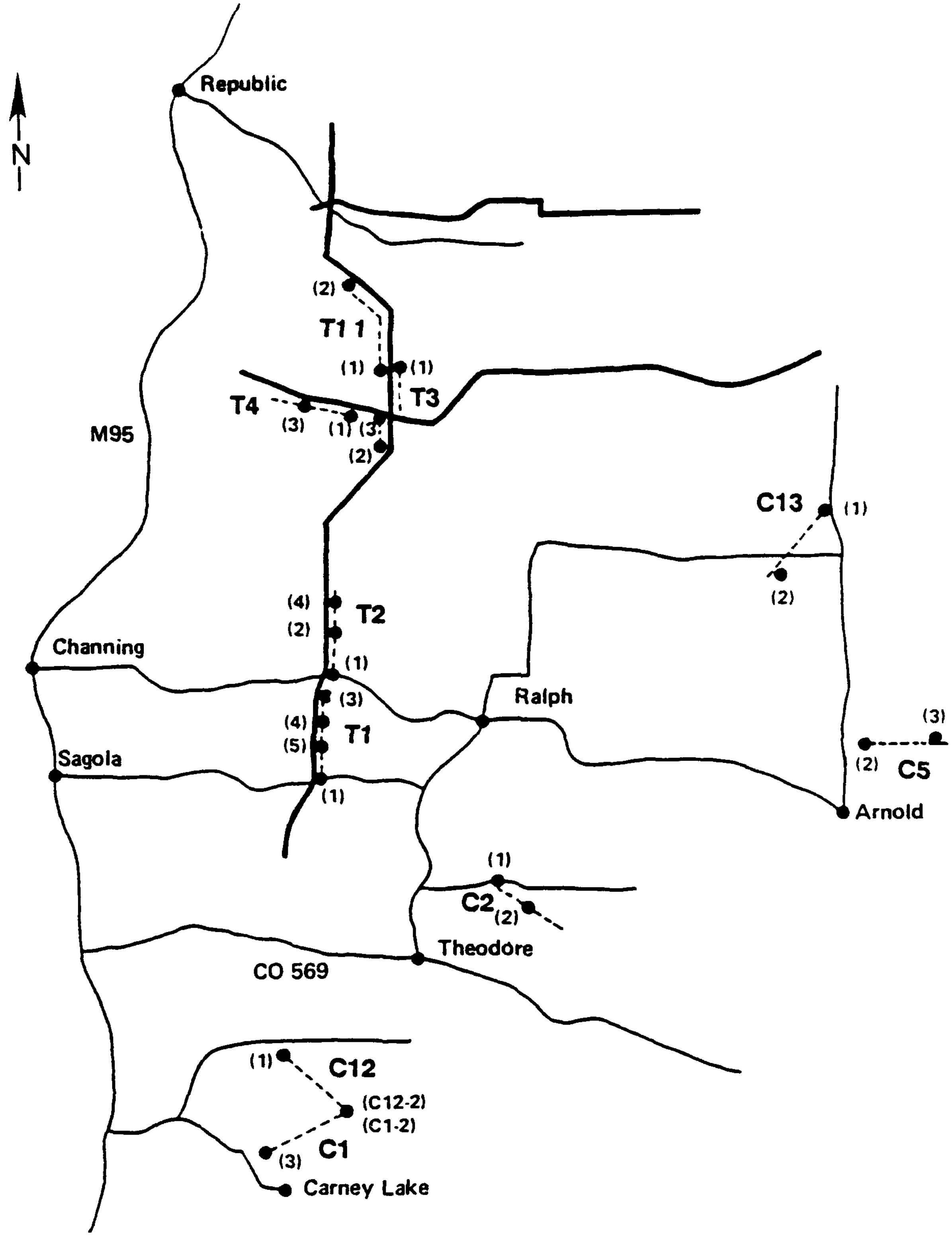


FIGURE G-2. POSITIONS OF BIRD SPECIES AND COMMUNITIES STUDY TRANSECTS RELATIVE TO MICHIGAN TRANSMITTING FACILITY ANTENNA ELEMENTS.

TABLE G-1. TRANSECT NO. CROSS-REFERENCE
Bird Species and Communities Studies

IITRI Transect No.	Investigator's Transect Name	Location: Township	:	Range	:	Section(s)
		Wisconsin				
10C6	Spillerberg Lake	T43N	:	R3W	:	23, 26, 35
10C7	Mineral Lake	T44N	:	R4W	:	15, 16, 17, 18
10C9	Blaisdell Lake	T40N	:	R3W	:	18
		T40N	:	R4W	:	13, 14, 22, 23
10C10	Brunet River	T40N	:	R3W	:	16, 21, 28
10C11	Rock Lake	T42N	:	R6W	:	6
		T43N	:	R6W	:	19, 30, 31
10T6	Moose River	T42N	:	R3W	:	31
		T42N	:	R4W	:	35, 36
10T7	Christy Lake	T42N	:	R5W	:	7, 8, 15, 16, 17
10T8	Little Clam Lake	T42N	:	R4W	:	5, 8, 17
10T9	Woodtick Lake	T43N	:	R4W	:	22, 23, 27, 28, 33
10T10	Black Lake	T41N	:	R5W	:	24, 25, 36
		Michigan				
10C1	Carney Lake	T41N	:	R29W	:	33, 34, 35, 36
10C2	Skunk Creek	T42N	:	R27W	:	19, 30
		T42N	:	R28W	:	14, 23, 24
10C5	Arnold	T43N	:	R25W	:	31, 32, 33, 34
10C12	Lost Lake	T41N	:	R29W	:	21, 26, 27, 28, 35
10C13	Bob's Creek	T44N	:	R26W	:	13, 23, 24, 26
10T1	Leeman's Road	T43N	:	R29W	:	14, 23, 26, 35
10T2	Turner Road	T43N	:	R29W	:	1, 12
		T44N	:	R29W	:	36
10T3	Flat Rock Creek	T45N	:	R28W	:	19, 30, 31
10T4	Schwartz Creek	T45N	:	R28W	:	31
		T45N	:	R29W	:	26, 27, 35, 36
10T11	Heart Lake	T45N	:	R28W	:	7, 18, 19
		T45N	:	R29W	:	1, 12

TABLE G-2. TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
BIRD SPECIES AND COMMUNITIES STUDIES
WISCONSIN TRANSECTS*

SITE NO.	1984 76 Hz		1985 76 Hz			1986 76 Hz	1987 76 Hz	1988 76 Hz	1989 76 Hz	1989 44 Hz
MEAS. PT.	NS	EW	NS	EW	B	B	B	B	B	B
10C6-1	<	<	/	/	<	<	<	<	<	<
10C6-2	<	<	/	/	<	<	<	<	<	<
10C7-2	<	<	<	/	<	<	<	<	<	<
10C7-3	-	-	<	<	<	<	<	<	<	<
10C9-1	<	<	/	/	<	<	<	<	<	<
10C9-2	<	<	/	/	<	<	<	<	<	<
10C10-1	<	<	/	/	<	<	<	<	<	<
10C10-2	<	<	/	/	<	<	--	--	--	--
10C10-3	-	-	-	-	-	-	<	<	<	<
10C11-1	-	-	<	<	<	<	<	<	<	<
10C11-2	-	-	<	<	<	<	<	<	<	<
10T6-1	0.006	0.195	/	/	/	0.166	0.22	0.22	0.24 (D)	0.177
10T6-2	0.014	0.107	/	/	/	0.090	0.077	0.135	0.070(D)	0.045
10T7-1	/	/	/	/	/	0.20	0.136	0.182	0.150(D)	0.120(D)
10T7-2	0.014	0.156	/	/	/	0.117	0.116	0.129	0.25 (D)	0.106(D)
10T7-3	0.015	0.183	/	/	/	0.129	0.110	0.121	0.22 (D)	0.091
10T8-2	0.089	0.013	/	/	/	0.067	0.094	0.078	0.087(D)	0.091
10T8-3	-	-	/	/	/	0.107	0.121	0.129	0.036(D)	0.108
10T8-4	-	-	/	/	/	0.078	0.087	0.072	0.086(D)	0.161
10T9-2	0.47	0.004	/	/	0.48	0.41	0.45	0.43	0.78 (D)	0.45
10T9-3	-	-	/	/	/	0.092	0.106	0.092	0.31 (D)	0.066
10T10-1	0.094	0.007	/	/	0.146	0.07	0.101	0.082	0.064(D)	0.058
10T10-2	0.195	0.006	/	/	0.163	0.091	0.082	0.087	0.133(D)	0.082

NS = north-south antenna.
EW = east-west antenna.
B = both antennas, standard phasing.
* = antenna current = 300 amperes.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
< = est. <0.002 V/m based on E-field in ground.
(D) = measurement taken during operation of dominant antenna only.

TABLE G-3. LONGITUDINAL ELECTRIC FIELD INTENSITIES (V/m)
BIRD SPECIES AND COMMUNITIES STUDIES
WISCONSIN TRANSECTS*

SITE NO.	1984		1985			1986	1987	1988	1989	
	76 Hz		76 Hz			76 Hz	76 Hz	76 Hz	76 Hz	44 Hz
MEAS. PT.	NS	EW	NS	EW	B	B	B	B	B	B
10C6-1	1.60	1.08	/	/	1.20	1.12	1.32	0.86	1.28	2.4
10C6-2	1.89	1.61	/	/	2.7	2.3	2.9	2.9	1.90	4.2
10C7-2	0.47	0.43	0.48	/	0.64	0.59	0.67	0.61	0.62	0.80
10C7-3	-	-	0.25,0.34	0.36	0.59	0.62	0.54	0.64	0.23	0.33
10C9-1	1.16	0.44	/	/	0.95	1.12	1.05	1.04	0.63	1.04
10C9-2	1.44	1.08	/	/	1.77	2.0	2.12	2.3	1.60	8.2
10C10-1	1.40	1.12	/	/	1.98	1.55	1.83	1.55	1.23	1.33
10C10-2	0.30	0.31	/	/	0.48	0.55	--	--	--	--
10C10-3	-	-	-	-	-	-	0.37	0.32	0.23	0.166
10C11-1	-	-	0.67	0.59	1.44	1.63	1.10	1.23	0.58	0.93
10C11-2	-	-	0.98	0.91	2.0	1.91	0.81	1.42	1.84	2.1
10T6-1	6.[illegible]	130	/	/	157	184	260	250	178(D)	144
10T6-2	12.8	88	14.1	95	77	82	76	56	43(D)	77
10T7-1	20	180	/	/	210	210	145	194	140(D)	123(D)
10T7-2	13.2	142	/	/	137	99	119	121	109(D)	97(D)
10T7-3	18.7	159	/	/	104	101	121	97	104(D)	62
10T8-2	102	15.2	/	/	81	90	84	115	89(D)	55
10T8-3	-	-	150	13.2	121	114	128	125	140(D)	83
10T8-4	-	-	73,85	23,24	71	63	70	86	86(D)	54
10T9-2	470	3.5	/	/	350	470	470	566	190(D)	390
10T9-3	-	-	81	7.8	71	88	114	89	95(D)	65
10T10-1	73	11.0	77	10.5	109	96	90	98	84(D)	51(D)
10T10-2	150	6.5	130	11.2	158	94	92	88	96(D)	67

NS = north-south antenna.
EW = east-west antenna.
B = both antennas, standard phasing.
* = antenna current = 300 amperes.

- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
(D) = measurement taken during operation of dominant antenna only.

TABLE G-4. MAGNETIC FLUX DENSITY (mG)
BIRD SPECIES AND COMMUNITIES STUDIES
WISCONSIN TRANSECTS*

SITE NO. MEAS. PT.	1984 76 Hz NS	1984 76 Hz EW	1985 76 Hz NS	1985 76 Hz EW	1985 76 Hz B	1986 76 Hz B	1987 76 Hz B	1988 76 Hz B	1989 76 Hz B	1989 44 Hz B
10C6-1	0.011	0.010	/	/	0.012	0.013	0.013	0.014	0.013	0.026
10C6-2	0.012	0.014	/	/	0.016	0.017	0.018	0.019	0.019	0.029
10C7-2	0.005	0.005	0.005	/	0.007	0.007	0.008	0.007	0.005	0.009
10C7-3	-	-	0.004,0.005	0.005	0.007	0.006	0.007	0.007	0.006	0.008
10C9-1	0.030	0.017	/	/	0.035	0.037	0.037	0.040	0.034	0.042
10C9-2	0.022	0.015	/	/	0.027	0.027	0.027	0.027	0.029	0.041
10C10-1	0.017	0.014	/	/	0.023	0.023	0.025	0.024	0.026	0.036
10C10-2	0.008	0.007	/	/	0.011	0.011	--	--	--	--
10C10-3	-	-	-	-	-	-	0.012	0.012	0.012	0.015
10C11-1	-	-	/	/	0.011	0.011	0.011	0.011	0.008	0.014
10C11-2	-	-	0.009	<0.001	0.014	0.014	0.014	0.015	0.015	0.017
10T6-1	0.041	3.6	/	/	8.8	9.0	9.0	10.2	9.2(D)	9.7
10T6-2	0.069	7.5	0.082	7.8	7.1	9.6	7.7	8.2	8.4(D)	8.6
10T7-1	0.061	4.7	/	/	4.4	4.2	5.2	4.8	4.8(D)	4.9(D)
10T7-2	0.059	2.3	/	/	2.2	2.2	2.3	2.3	2.4(D)	2.4(D)
10T7-3	0.094	4.9	/	/	4.7	4.6	4.8	5.1	4.9(D)	5.1
10T8-2	4.9	0.136	/	/	4.8	4.9	5.0	5.2	5.1(D)	5.0
10T8-3	-	-	9.9	0.127	8.1	8.4	8.5	8.5	8.8(D)	9.0
10T8-4	-	-	3.4,6.6	0.192	3.4	3.4	3.6	3.6	3.7(D)	3.5
10T9-2	1.58	0.033	/	/	2.4	2.2	2.2	2.1	2.2(D)	2.3
10T9-3	-	-	4.1	0.072	3.4	3.7	3.9	3.8	3.2(D)	3.2
10T10-1	4.5	0.063	4.5	0.066	5.7	4.3	4.5	4.5	4.6(D)	4.4(D)
10T10-2	4.9	0.050	3.7	0.042	4.7	3.9	3.9	4.0	4.2(D)	4.1

NS = north-south antenna.
EW = east-west antenna.
B = both antennas, standard phasing.
* = antenna current = 300 amperes.

- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
(D) = measurement taken during operation of dominant antenna only.

TABLE G-5. 60 Hz EM FIELD MEASUREMENTS--1984, 1985, AND 1989
BIRD SPECIES AND COMMUNITIES STUDIES
WISCONSIN TRANSECTS

SITE NO., MEAS. PT.	TRANSVERSE ELECTRIC FIELD INTENSITY (V/m) 1984	1985	1989	LONGITUDINAL ELECTRIC FIELD INTENSITY (mV/m) 1984	1985	1989	MAGNETIC FLUX DENSITY (mG) 1984	1985	1989
10C6-1	<	<	<	0.063	0.098	0.075	0.001	0.001	0.001
10C6-2	<	<	<	0.100	0.089	0.086	0.001	<0.001	0.001
10C7-2	<	<	<	0.053	0.051,0.055	0.044	<0.001	<0.001	<0.001
10C7-3	-	<	<	-	0.074, 0.93, 0.104, 0.27	0.303	-	0.001,<0.001	<0.001
10C9-1	<	<	<	0.098	0.21	0.23	0.001	0.002	0.002
10C9-2	<	<	<	0.013	0.065	0.062	<0.001	<0.001	0.001
10C10-1	<	<	<	0.016	0.055	0.020	<0.001	<0.001	<0.001
10C10-2	<	<	--	0.024	0.053	--	0.001	0.001	--
10C10-3	-	-	<	-	-	0.015	-	-	<0.001
10C11-1	-	<	<	-	0.23,0.32	0.25	-	0.002	0.002
10C11-2	-	<	<	-	0.038, 0.040, 0.071	0.035	-	0.001,<0.001	0.001
10T6-1	<0.001	<	<0.001	0.044	0.033	0.042	<0.001	0.001	0.001
10T6-2	<0.001	<	<0.001	0.022	0.020	0.026	0.001	0.001	0.001
10T7-1	<	<	<	0.040	0.047	0.061	0.001	0.001	0.001
10T7-2	<0.001	<	<0.001	0.100	0.087	0.127	<0.001	0.001	0.001
10T7-3	<0.001	<	0.002	0.096	0.066	0.110	0.001	0.001	0.002
10T8-2	<0.001	<	<	0.045	0.040	0.044	0.001	0.002	<0.001
10T8-3	-	<	<0.001	-	0.100,0.110	0.132	-	0.002,0.003	0.001
10T8-4	-	<	<0.001	-	0.032,0.038	0.017	-	0.001,0.002	0.001
10T9-2	<0.001	<	<0.001	0.130	0.071	0.112	<0.001	<0.001	0.001
10T9-3	-	<	<0.001	-	0.028,0.036	0.038	-	0.002,<0.001	0.001
10T10-1	<0.001	<	<	0.040	0.074	0.026	0.001	0.001	<0.001
10T10-2	<0.001	<	<0.001	0.091	0.126	0.023	0.001	0.001	<0.001

\- = measurement point not established.
-- = measurement point dropped.
< = est. <0.001 V/m based on E-field in ground.

TABLE G-6. EM FIELD GRADIENTS PERPENDICULAR TO TRANSECT 10T8
Bird Species and Communities Studies

Distance from Antenna (meters)	Magnetic Flux Density (mG)	Electric Field Intensity (mV/m)
0 under wire	109	197
19 edge of ROW	32	151
25	23	126
50	11.7	109
75	8.3	91
86 transect 10T8	7.3	119
100	6.2	106
125	5.1	96
150	4.3	76
200	3.2	76
250 east side of GG	2.6	69
300 west side of GG	2.2	95

Notes: Measurement transect begins 41 m south of pole PIN66 and bears nominally to the west. It crosses study transect 10T8 between the E and F transect segments. Antenna conditions: 300 amperes, 76 Hz modulated, -75° phasing.

TABLE G-7. EM FIELD VARIATIONS ALONG WISCONSIN TRANSECTS
Bird Species and Communities Studies
(page 1 of 2)

Study Transect	Subtransect Location	Magnetic Flux Density (mG)	Electric Field Intensity (mV/m)
10C7-3	Start A	0.0060	0.64
10C7	A-X-B	0.0061	1.13
10C7	B-X-C	0.0063	1.35
10C7	C-X-D	0.0064	0.83
10C7	D-X-E	0.0068	0.40
10C7	E-X-F	0.0070	0.45
10C7-2	F-14	0.0074	0.61
10C7	F-X-G	0.0077	0.97
10C7	G-X-H	0.0079	0.99
10C7	End H	0.0084	1.29
10T6	Start A	4.3	103
10T6	A-X-B	6.1	121
10T6	B-X-C	4.3	95
10T6	C-X-D	5.6	116
10T6	D-X-E	6.5	81
10T6	E-X-F	7.6	78
10T6	F-X-G	3.6	140
10T6-2	G-X-H	8.4	43
10T6	End H	9.7	117
10T7-1	Start A	4.8	140
10T7	A-X-B	4.5	117
10T7	B-X-C	2.5	76
10T7-2	C8	2.4	109
10T7	C-X-D	2.3	51
10T7	D-X-E	9.4	152
10T7	E-X-F	5.2	106
10T7	F-X-G	7.6	133
10T7	G-X-H	4.6	99
10T7-3	H8	4.9	104
10T7	End H	4.6	98

Notes: Measurements taken at "X" flag between subtransects except as noted.
Antenna conditions: 300 amperes, 76 Hz.
Transects 10T6, 10T7, 10T9 and 10T10 measured in 1989.
Transects 10C7 and 10T8 measured in 1988.

TABLE G-7. EM FIELD VARIATIONS ALONG WISCONSIN TRANSECTS
Bird Species and Communities Studies
(page 2 of 2)

Study Transect	Subtransect Location	Magnetic Flux Density (mG)	Electric Field Intensity (mV/m)
10T8	Start B	6.7	80
10T8-3	B-X-C	8.5	125
10T8	C-X-D	7.6	88
10T8	D-X-E	6.9	166
10T8	E-X-F	7.5	96
10T8-2	Hwy GG	5.2	115
10T8	F-X-G	12.1	162
10T8	G-X-H	5.9	119
10T8	H-X-I	3.5	216
10T8-4	I-13	3.6	90
10T8	I-X-J	4.0	105
10T8	End J	3.1	73
10T9	Start B	5.4	101
10T9	B-X-C	2.6	140
10T9	C-X-D	4.9	127
10T9	D-X-E	2.7	90
10T9	E-X-F	2.2	127
10T9	F-X-G	2.7	260
10T9	G-X-H	2.7	126
10T9-2	H9	2.2	190
10T9	END H	1.42	140
10T10-1	Start A	4.6	84
10T10	Start B	4.4	84
10T10	B-X-C	5.4	112
10T10	C-X-D	7.3	166
10T10	D-X-E	8.0	97
10T10	E-X-F	4.2	80
10T10-2	F6	4.2	96
10T10	F-X-G	5.3	53
10T10	G-X-H	3.4	52
10T10	End H	3.4	175

Notes: Measurements taken at "X" flag between subtransects except as noted.
Antenna conditions: 300 amperes, 76 Hz.
Transects 10T6, 10T7, 10T9 and 10T10 measured in 1989.
Transects 10C7 and 10T8 measured in 1988.

TABLE G-8. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Bird Species and Communities Studies
Michigan Transects

Site No., Meas. Pt.	1983 [a]	1984 [a]	1985 [a]	1986 [b]	1987 [c]	1988 [c]	1989 [d]
10C1-2	-	<	<	<	<	<	<
10C1-3	-	-	<	<	<	<	<
10C2-1	-	<	<	<	<	<	<
10C2-2	-	<	<	<	<	<	<
10C5-2	-	<	<	<	<	<	<
10C5-3	-	<	<	<	<	<	<
10C12-1	-	-	<	<	<	<	<
10C12-2	-	-	<	<	<	<	<
10C13-1	-	-	<	<	<	<	<
10C13-2	-	-	<	<	<	<	<
10T1-1	-	<	<	<	<	<	<0.001
10T1-3	-	-	<	<	<	<	<
10T1-4	-	-	-	<	<	<	<
10T1-5	-	-	-	<	<	<	<0.001
10T2-1	-	<0.001	<	<	<	<	<
10T2-2	-	-	-	<	<	<	<
10T2-4	-	-	<	<	<	0.008	#
10T3-1	-	<	<	<	<	<	<
10T3-2	-	<	<	<	<	<	<
10T3-3	-	-	-	<	<	<0.001	<0.001
10T4-1	-	<	<	<	<	<	<
10T4-3	-	-	-	<	<	<	<
10T11-1	-	-	<	<	<	<0.001	<0.001
10T11-2	-	-	<	<	0.011	<0.001	<0.001

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

\- = measurement point not established.
\# = measurement not possible.
< = est. <0.001 V/m based on E-field in ground.

TABLE G-9. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITES (mV/m)
Bird Species and Communities Studies
Michigan Transects

Site No., Meas. Pt.	1983 [a]	1984 [a]	1985 [a]	1986 [b]	1987 [c]	1988 [c]	1989 [d]
10C1-2	-	0.62	0.106,0.141	0.101	0.059	0.20	0.073
10C1-3	-	-	0.26,0.27	0.055	0.21	0.32	0.72
10C2-1	-	0.98	0.138	0.041	0.038	0.087	0.080
10C2-2	-	0.35	0.21	0.055	0.048	0.047	0.069
10C5-2	-	0.35	0.45	0.193	0.116	0.23	0.053
10C5-3	-	0.111	0.23	0.25	0.103	0.126	0.050
10C12-1	-	-	0.194,0.28	0.058	0.256	0.98	1.19
10C12-2	-	-	0.106,0.141	0.101	0.059	0.20	0.073
10C13-1	-	-	0.34,0.52	0.30	0.40	0.37	0.78
10C13-2	-	-	0.143,0.31	0.139	0.157	0.121	0.039
10T1-1	-	0.076	0.061	0.034	0.099	0.21	0.077
10T1-3	-	-	0.38	0.120	0.20	0.51	#
10T1-4	-	-	-	0.111	0.085	0.30	0.076
10T1-5	-	-	-	0.040	0.052	0.116	0.052
10T2-1	-	0.42	0.194	0.050	0.058	0.23	0.034
10T2-2	-	-	-	0.058	0.052	0.24	0.023
10T2-4	-	-	0.158	0.054	0.029	0.166	0.164
10T3-1	-	0.30	0.23	0.145	0.164	0.070	#
10T3-2	-	0.26	0.117	0.069	0.103	0.075	#
10T3-3	-	-	-	0.094	0.120	0.132	0.32
10T4-1	-	0.29	0.132	0.129	0.093	0.087	#
10T4-3	-	-	-	0.112	0.22	0.166	0.087
10T11-1	-	-	0.23	0.172	0.106	0.095	0.25
10T11-2	-	-	0.26,0.50	0.58	0.45	0.196	0.21

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

\- = measurement point not established.
= measurement not possible.

TABLE G-10. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Bird Species and Communities Studies
Michigan Transects

Site No., Meas. Pt.	1983 [a]	1984 [a]	1985 [a]	1986 [b]	1987 [c]	1988 [c]	1989 [d]
10C1-2	-	0.001	0.001	<0.001	<0.001	0.001	0.001
10C1-3	-	-	0.001,0.003	<0.001	0.003	0.002	0.007
10C2-1	-	0.005	0.004	<0.001	<0.001	<0.001	0.001
10C2-2	-	0.003	0.003	<0.001	0.001	0.001	0.001
10C5-2	-	0.008	0.009	0.006	0.005	0.006	0.002
10C5-3	-	0.001	0.002	0.002	0.001	0.001	0.001
10C12-1	-	-	0.001,0.003	0.002	0.003	0.011	0.009
10C12-2	-	-	0.001	<0.001	<0.001	0.001	0.001
10C13-1	-	-	0.007,0.010	0.007	0.005	0.003	0.009
10C13-2	-	-	0.001,<0.001	0.001	0.001	0.001	0.001
10T1-1	-	0.006	0.004	0.002	0.005	0.016	0.005
10T1-3	-	-	0.002	0.003	0.005	0.017	#
10T1-4	-	-	-	0.003	0.003	0.009	0.002
10T1-5	-	-	-	0.003	0.016	0.012	0.003
10T2-1	-	0.002	0.002	0.003	0.005	0.012	0.001
10T2-2	-	-	-	<0.001	0.002	0.008	0.001
10T2-4	-	-	0.001	0.002	0.001	0.004	0.001
10T3-1	-	0.001	0.001	0.006	0.003	0.004	#
10T3-2	-	0.001	<0.001	0.008	0.005	0.004	#
10T3-3	-	-	-	0.012	0.007	0.017	0.010
10T4-1	-	0.001	<0.001	0.002	0.002	0.003	#
10T4-3	-	-	-	0.001	0.003	0.004	0.002
10T11-1	-	-	<0.001	0.006	0.006	0.003	0.003
10T11-2	-	-	0.001,<0.001	0.008	0.005	0.004	<0.001

a = prior to antenna construction.
b = antennas grounded at transmitter.
c = antennas off, connected to transmitter.
d = both antennas on, 150 A current.

\- = measurement point not established.
= measurement not possible.

TABLE G-11. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Bird Species and Communities Studies
Michigan Transects

Site No., Meas. Pt.	1986 NS 4 amps	1986 NEW 6 amps	1986 SEW 6 amps	1986 SEW 10 amps (EX)	1987 NS 15 amps	1987 EW 15 amps	1988 NS 75 amps	1988 EW 75 amps	1989 B 150 amps
10C1-2	<	<	<	*	<	<	<	<	<
10C1-3	<	<	<	*	<	<	<	<	<
10C2-1	<	<	<	*	<	<	<	<	<
10C2-2	<	<	<	*	<	<	<	<	<
10C5-2	<	<	<	*	<	<	<	<	<
10C5-3	<	<	<	*	<	<	<	<	<
10C12-1	<	<	<	*	<	<	<	<	<
10C12-2	<	<	<	*	<	<	<	<	<
10C13-1	<	<	<	*	<	<	<	<	<
10C13-2	<	<	<	*	<	<	<	<	<
10T1-1	<	<	<	*	0.005	<	0.022	<	0.036
10T1-3	0.002	<	<	*	0.007	<	0.038	<0.001	0.068
10T1-4	<	<	<	*	0.004	<	0.024	<	0.036
10T1-5	<	<	<	*	0.003	<	0.010	<	0.022
10T2-1	0.002	<	<	*	0.006	<	0.033	<0.001	0.059
10T2-2	0.002	<	<	*	0.007	<	0.047	0.003	0.062
10T2-4	0.002	<	<	*	0.007	<	0.028	0.007	0.062
10T3-1	0.004	<	<	*	0.005	0.003	0.016	0.019	0.040
10T3-2	0.004	<	0.001	0.002	0.006	0.003	0.048	0.034	0.071
10T3-3	0.005	<	0.017	0.028	0.005	0.009	0.046	0.120	0.170
10T4-1	0.002	<	0.003	0.005	0.003	0.006	0.042	0.038	0.049
10T4-3	<	<	0.003	0.005	0.001	0.008	0.018	0.054	0.078
10T11-1	<	<	<	*	0.004	0.002	0.019	0.014	0.051
10T11-2	<	<	<	*	0.038	0.009	0.059	0.017	0.108

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.

EX = extrapolated data.
* = data cannot be extrapolated.
< = est. <0.001 V/m based on E-field in ground.

TABLE G-12. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Bird Species and Communities Studies
Michigan Transects

Site No., Meas. Pt.	1986				1987		1988		1989
	NS 4 amps	NEW 6 amps	SEW 6 amps	SEW 10 amps (EX)	NS 15 amps	EW 15 amps	NS 75 amps	EW 75 amps	B 150 amps
10C1-2	0.004	0.003	0.004	0.007	0.015	0.012	0.074	0.058	0.153
10C1-3	0.013	0.004	0.002	0.003	0.049	0.011	0.26	0.060	0.41
10C2-1	0.017	0.002	0.007	0.012	0.073	0.021	0.30	0.095	0.78
10C2-2	0.011	0.003	0.007	0.012	0.037	0.020	0.176	0.100	0.33
10C5-2	0.001	0.003	0.007	0.012	0.014	0.023	0.073	0.119	0.26
10C5-3	0.005	0.003	0.009	0.015	0.017	0.027	0.091	0.143	0.30
10C12-1	0.028	0.010	0.011	0.018	0.068	0.028	0.36	0.140	1.37
10C12-2	0.004	0.003	0.004	0.007	0.015	0.012	0.074	0.058	0.153
10C13-1	0.024	0.027	0.104	0.173	0.057	0.24	0.32	1.39	4.8
10C13-2	0.024	0.023	0.098	0.163	0.089	0.29	0.34	1.07	2.1
10T1-1	0.85	0.028	0.008	0.013	2.8	0.015	13.0	0.115	42
10T1-3	2.2	0.068	0.077	0.128	7.1	0.147	33	0.86	74
10T1-4	0.96	0.030	0.031	0.052	4.1	0.087	19.8	0.46	35
10T1-5	0.65	0.020	0.006	0.010	2.3	0.015	10.9	0.098	20
10T2-1	1.42	0.043	0.077	0.128	5.3	0.25	31	1.05	48
10T2-2	1.69	0.056	0.107	0.178	7.0	0.34	33	1.77	53
10T2-4	0.59	0.056	0.158	0.26	5.0	0.49	26	2.6	79
10T3-1	0.82	0.23	0.60	1.00	4.9	2.1	26	10.1	47
10T3-2	1.24	0.133	1.05	1.75	5.4	2.7	21	31	61
10T3-3	1.36	(0.35)	3.6	6.0	4.8	7.5	43	54	111
10T4-1	0.88	0.137	1.58	2.6	2.4	4.8	14.5	19.3	62
10T4-3	0.46	0.139	1.92	3.2	1.30	8.1	5.4	39	68
10T11-1	0.67	0.27	0.59	0.98	3.9	1.97	17.6	8.9	47
10T11-2	1.38	0.93	0.44	0.73	7.3	2.9	32	12.6	105

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.

EX = extrapolated data.
() = estimated data.

TABLE G-13. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Bird Species and Communities Studies
Michigan Transects

Site No., Meas. Pt.	1986 NS 4 amps	1986 NEW 6 amps	1986 SEW 6 amps	1986 SEW 10 amps (EX)	1987 NS 15 amps	1987 EW 15 amps	1988 NS 75 amps	1988 EW 75 amps	1989 B 150 amps
10C1-2	<0.001	<0.001	<0.001	*	<0.001	<0.001	<0.001	<0.001	0.001
10C1-3	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.002	<0.001	0.003
10C2-1	<0.001	<0.001	<0.001	*	0.001	0.001	0.005	0.002	0.009
10C2-2	<0.001	<0.001	<0.001	*	0.001	<0.001	0.003	0.002	0.005
10C5-2	<0.001	<0.001	<0.001	*	<0.001	0.001	0.001	0.002	0.005
10C5-3	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	0.001	0.003
10C12-1	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.002	0.001	0.004
10C12-2	<0.001	<0.001	<0.001	*	<0.001	<0.001	<0.001	<0.001	0.001
10C13-1	<0.001	<0.001	<0.001	*	0.001	0.002	0.002	0.009	0.066
10C13-2	<0.001	<0.001	<0.001	*	<0.001	0.001	0.002	0.006	0.015
10T1-1	0.044	0.001	<0.001	*	0.179	0.001	0.84	0.005	1.87
10T1-3	0.047	0.001	0.007	0.012	0.176	0.001	0.84	0.010	1.70
10T1-4	0.026	0.001	0.001	0.002	0.103	0.002	0.49	0.014	1.02
10T1-5	0.034	0.001	0.001	0.002	0.49	0.002	0.61	0.008	1.31
10T2-1	0.066	0.002	0.001	0.002	0.25	0.001	1.21	0.010	2.5
10T2-2	0.043	0.001	0.001	0.002	0.165	0.002	0.80	0.010	1.61
10T2-4	0.026	0.001	0.001	0.002	0.097	0.002	0.46	0.005	0.97
10T3-1	0.029	0.003	0.007	0.012	0.188	0.015	0.96	0.078	1.89
10T3-2	0.081	0.002	0.013	0.022	0.29	0.031	1.61	0.161	2.9
10T3-3	0.116	(0.040)	0.58	0.97	0.196	0.89	1.11	7.7	15.0
10T4-1	0.025	0.001	0.081	0.135	0.038	0.191	0.20	1.00	1.92
10T4-3	0.025	0.001	0.119	0.198	0.011	0.32	0.051	1.42	2.9
10T11-1	0.033	0.002	0.006	0.010	0.24	0.015	1.09	0.072	2.3
10T11-2	0.042	0.003	0.003	0.005	0.31	0.006	1.42	0.033	2.9

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.

EX = extrapolated data.
() = estimated data.
* = data cannot be extrapolated.

APPENDIX H

ELECTROMAGNETIC EXPOSURE CRITERIA

ELECTROMAGNETIC EXPOSURE CRITERIA

Because the electromagnetic (EM) intensity and operational characteristics required to produce a bioeffect are not known, EM exposure criteria were established to assist investigators in selecting study sites. The exposure criteria ensure that the 76 Hz EM fields at a test site are significantly larger than the 76 Hz EM fields at the control site, the 60 Hz EM fields at the test site, and the 60 Hz EM fields at the control site. In addition, the exposure criteria verify that there is not a substantial difference in the ambient 60 Hz EM field intensities between the test and control sites.

The EM exposure criteria used in site selection are expressed in equation form as follows:

$$T_{(76\ \mathrm{Hz})}/C_{(76\ \mathrm{Hz})} > 10 \qquad (1)$$

$$T_{(76\ \mathrm{Hz})}/T_{(60\ \mathrm{Hz})} > 10 \qquad (2)$$

$$T_{(76\ \mathrm{Hz})}/C_{(60\ \mathrm{Hz})} > 10 \qquad (3)$$

$$0.1 < T_{(60\ \mathrm{Hz})}/C_{(60\ \mathrm{Hz})} < 10 \qquad (4)$$

where $T_{(76\ \mathrm{Hz})}$ = test site exposure due to ELF Communications System

$T_{(60\ \mathrm{Hz})}$ = test site exposure due to power lines

$C_{(76\ \mathrm{Hz})}$ = control site exposure due to ELF Communications System

$C_{(60\ \mathrm{Hz})}$ = control site exposure due to power lines

Based on the exposure assessment, each possible test and control site pairing was classified as acceptable, conditionally acceptable, or unacceptable. These categories are defined as follows:

> <u>Acceptable</u>. A test/control site pair was placed in this category if it satisfied all four EM exposure inequalities for each of the EM fields applicable to the study. For example, the small mammals and nesting birds studies would be concerned with both the soil and air electric fields as well as the magnetic fields. The soil arthropods and earthworms studies, however, would not be concerned with the electric field in the air, since this field terminates at the earth's surface and would not be expected to impact biota existing in the soil or litter layer.
>
> <u>Conditionally Acceptable</u>. A test/control site pair was placed in this category if it approached, but did not meet, the criteria for acceptability. This category was established because the EM exposure criteria were not rigidly defined. The assumption was made

that a difference of one order of magnitude or more would constitute a significant difference between test and control sites for these studies, but without knowing what effects will be experienced, if any. It is difficult to define this difference *a priori*. Furthermore, the EM field measurements themselves encompass a certain degree of error, as do any physical measurements.

Unacceptable. A test/control site pair was placed in this category if it neither satisfied the criteria for acceptability nor qualified for conditional acceptability.

APPENDIX I

ELECTROMAGNETIC MEASUREMENTS VS. ANTENNA PHASE OF NRTF-CLAM LAKE

ELECTROMAGNETIC MEASUREMENTS VS. ANTENNA PHASE OF NRTF-CLAM LAKE

Tables I-1 through I-3 document EM field measurements as a function of the antenna current phase angle of the NRTF-Clam Lake for study sites 10T6-2, 10T8-4, and 10T10-1, respectively.

These data can be used to relate measurements taken in previous years to measurements at any antenna current phase angle. They may also be used to estimate the EM field levels at phase angles for which measurements have not been made. For the longitudinal electric field, the data tables also give a correction factor that can be used to calculate the maximum EM field magnitude from the vector sum magnitude for the measured phase angles. Correction factors for other phase angles can be linearly extrapolated from those in the tables. This has already been done for -75°, the most commonly used condition at the NRTF-Clam Lake.

TABLE I-1. EM MEASUREMENTS VS. ANTENNA PHASE FOR 10T6-2

Site No., Meas. Pt.	Antenna Current Phase,* Degrees	Longitudinal Electric Field Intensity (mV/m)		Correction Factor:	Magnetic Flux Density (mG)	
		Vector Sum E_{VS}	Measured Max. E_{MAX}	E_{MAX}/E_{VS}	Vector Sum B_{VS}	Vertical Component $B_{Vert.}$
10T6-2	NS only	14.1 15.0	1.06	0.082	0.049	
	EW only	95	95	1.00	7.8	7.7
	0	95	95	1.00	7.8	7.7
	-30	95	95	1.00	7.8	7.7
	-60	93	95	1.02	7.8	7.7
	-75		1.02			
	-90	93	95	1.02	7.8	7.7
	-120	93	95	1.02	7.8	7.7
	-150	92	95	1.03	7.8	7.7
	-180	95	95	1.00	7.8	7.7
	-210	95	95	1.00	7.8	7.7
	-240	97	95	0.98	7.8	7.7
	-270	97	95	0.98	7.8	7.7
	-300	97	95	0.98	7.8	7.7
	-330	96	95	0.99	7.8	7.7

*Defined as the phase of the NS antenna current with respect to the EW antenna current.

TABLE I-2. EM MEASUREMENTS VS. ANTENNA PHASE FOR 10T8-4

Site No., Meas. Pt.	Antenna Current Phase,* Degrees	Longitudinal Electric Field Intensity (mV/m)		Correction Factor:	Magnetic Flux Density (mG)	
		Vector Sum E_{VS}	Measured Max. E_{MAX}	E_{MAX}/E_{VS}	Vector Sum B_{VS}	Vertical Component $B_{Vert.}$
10T8-4	NS only	85	82	0.96	3.4	3.4
	EW only	23	24	1.02	0.192	0.160
	0	88	84	0.95	3.7	3.6
	-30	84	82	0.98	3.7	3.6
	-60	84	80	0.95	3.7	3.6
	-75		0.95			
	-90	86	82	0.95	3.6	3.5
	-120	86	82	0.95	3.6	3.5
	-150	89	82	0.92	3.3	3.3
	-180	91	90	0.99	3.5	3.4
	-210	91	93	1.02	3.3	3.3
	-240	91	94	1.03	3.5	3.4
	-270	91	90	0.99	3.5	3.4
	-300	85	85	1.00	3.6	3.5
	-330	88	84	0.95	3.6	3.5

*Defined as the phase of the NS antenna current with respect to the EW antenna current.

TABLE I-3. EM MEASUREMENTS VS. ANTENNA PHASE FOR 10T10-1

Site No., Meas. Pt.	Antenna Current Phase,* Degrees	Longitudinal Electric Field Intensity (mV/m)		Correction Factor:	Magnetic Flux Density (mG)	
		Vector Sum E_{VS}	Measured Max. E_{MAX}	E_{MAX}/E_{VS}	Vector Sum B_{VS}	Vertical Component $B_{Vert.}$
10T10-1	NS only	77	82	1.06	4.5	4.5
	EW only	10.5	10.5	1.00	0.066	0.030
	0	79	80	1.01	4.5	4.5
	-30	80	83	1.04	4.5	4.5
	-60	80	84	1.05	4.5	4.5
	-75		1.05			
	-90	80	84	1.05	4.5	4.5
	-120	79	83	1.05	4.5	4.5
	-150	78	81	1.04	4.6	4.6
	-180	78	81	1.04	4.6	4.6
	-210	78	82	1.05	4.6	4.6
	-240	78	82	1.05	4.6	4.6
	-270	78	81	1.04	4.6	4.6
	-300	78	80	1.03	4.6	4.6
	-330	79	80	1.01	4.5	4.5

*Defined as the phase of the NS antenna current with respect to the EW antenna current.

APPENDIX J

ELECTROMAGNETIC EXPOSURE SETUP PROTOCOLS FOR SOIL AMOEBA STUDIES

ELECTROMAGNETIC EXPOSURE SETUP PROTOCOLS FOR SOIL AMOEBA STUDIES

This appendix documents the protocol written by IITRI to assist the soil amoeba study investigator in setting up his study sites using the culture cell exposure hardware fabricated by IITRI. This protocol also provides guidelines for proper adjustment of the EM exposures and monitoring of the exposure parameters using this equipment.

EXPOSURE SETUP PROTOCOLS
FOR SOIL AMOEBA STUDIES

MATCHED ELECTRIC FIELD PROTOCOL

(1) Measure maximum electric field, E, in soil, using 1-meter probe.

(2) Multiply electric field value by 0.15 to determine the minimum required drive voltage, V_{DR} (min).

$$V_{DR}\,(\text{min}) = E \times 0.15 \text{ (volts)}$$

(3) Locate collector electrodes in line with the maximum electric field in the earth, and spaced far enough apart to generate a voltage across a 2000-ohm resistor that is greater than or equal to V_{DR} (min) (see Figure J-1).

(4) Measure and record electrode spacing and the open circuit (no load) electrode voltage, V_{OC}.

(5) Connect the test cell and control box to the electrodes (see Figure J-2). While monitoring the test cell voltage, V_{CL}, adjust the variable resistor so that V_{CL} is equal to the value given by the following formula:

$$V_{CL} = E \times 0.113 \text{ (volts)}$$

(6) With the cell voltage set, measure and record the voltage across the 100-ohm series resistor, V_R. This allows calculation of the cell current and current density.

(7) Measure and record the electrode voltage, V_{DR}, with the test cell and monitoring box connected and adjusted as per Step 5, above.

MATCHED CURRENT DENSITY PROTOCOL

(1) Measure maximum electric field, E, in soil, using 1-meter probe.

(2) Locate collector electrodes in line with maximum electric field, with a separation of 1 meter.

(3) Measure exact electrode spacing and open circuit (no load) electrode voltage, V_{OC}. Measured voltage should be within a few percent of that measured in Step 1. If not, correct electrode spacing as appropriate.

(4) Connect current-limiting control box (see Figure J-3) to electrodes. Place the current limit select switch to the 2.5-megohm position (2.5 M).

(5) Measure and record the voltages across the test cell, V_{CL}, the resistor, V_R, and the electrodes, V_{DR}, using the test point jacks (see Figure J-3 for test point numbering).

The voltages across the resistor and across the electrodes should be close in value to V_{OC} from Step 3.

$$V_R \simeq V_{DR} \simeq V_{OC}$$

The voltage across the test cell will be much lower, and can be estimated as:

$$V_{CL} \simeq 0.6 \times 10^{-3} \times V_{OC} \text{ (volts).}$$

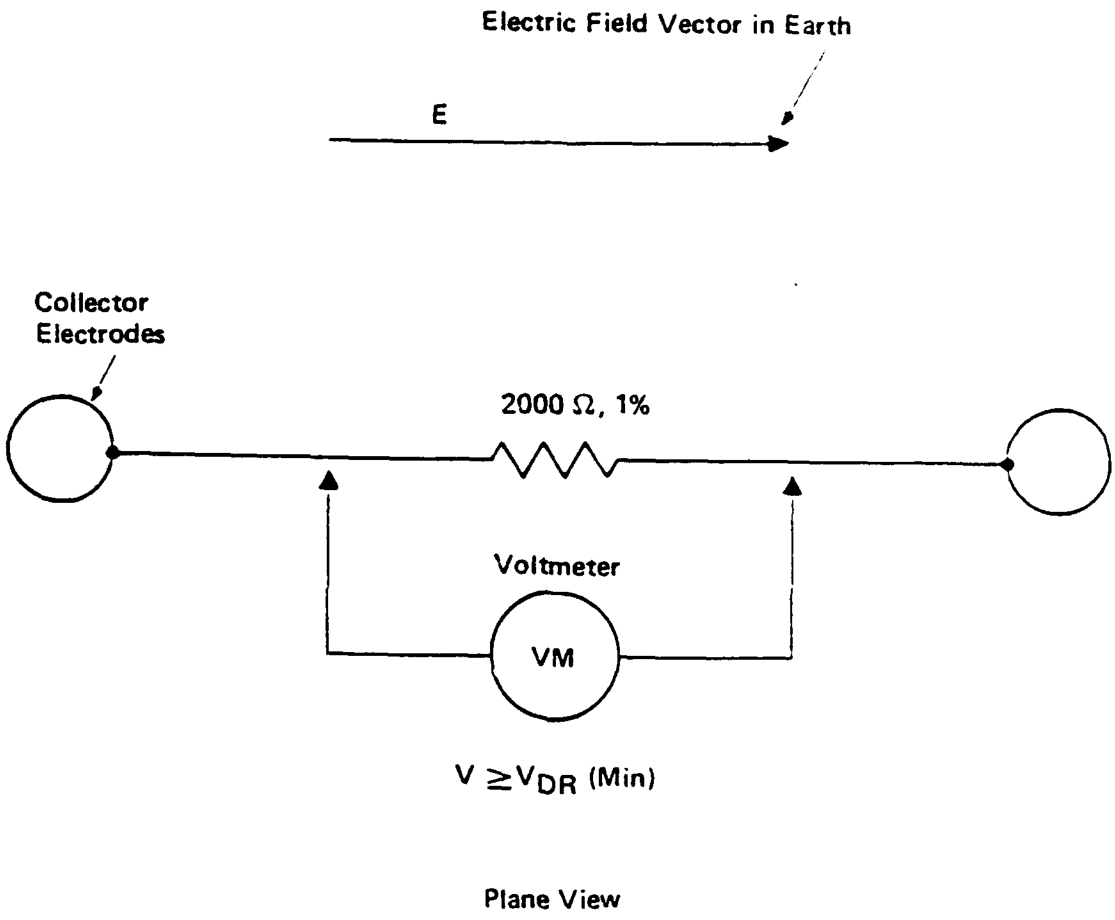
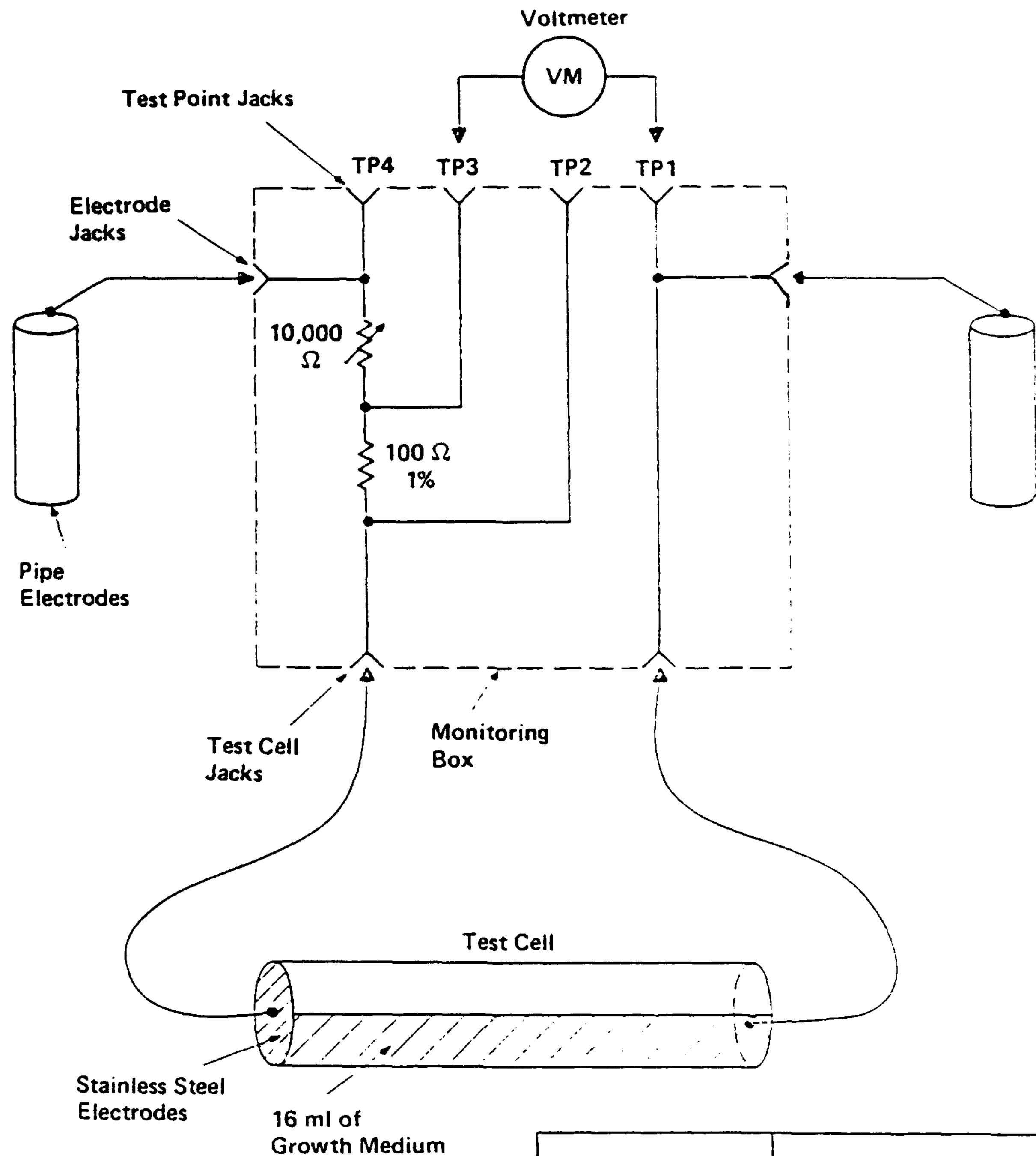


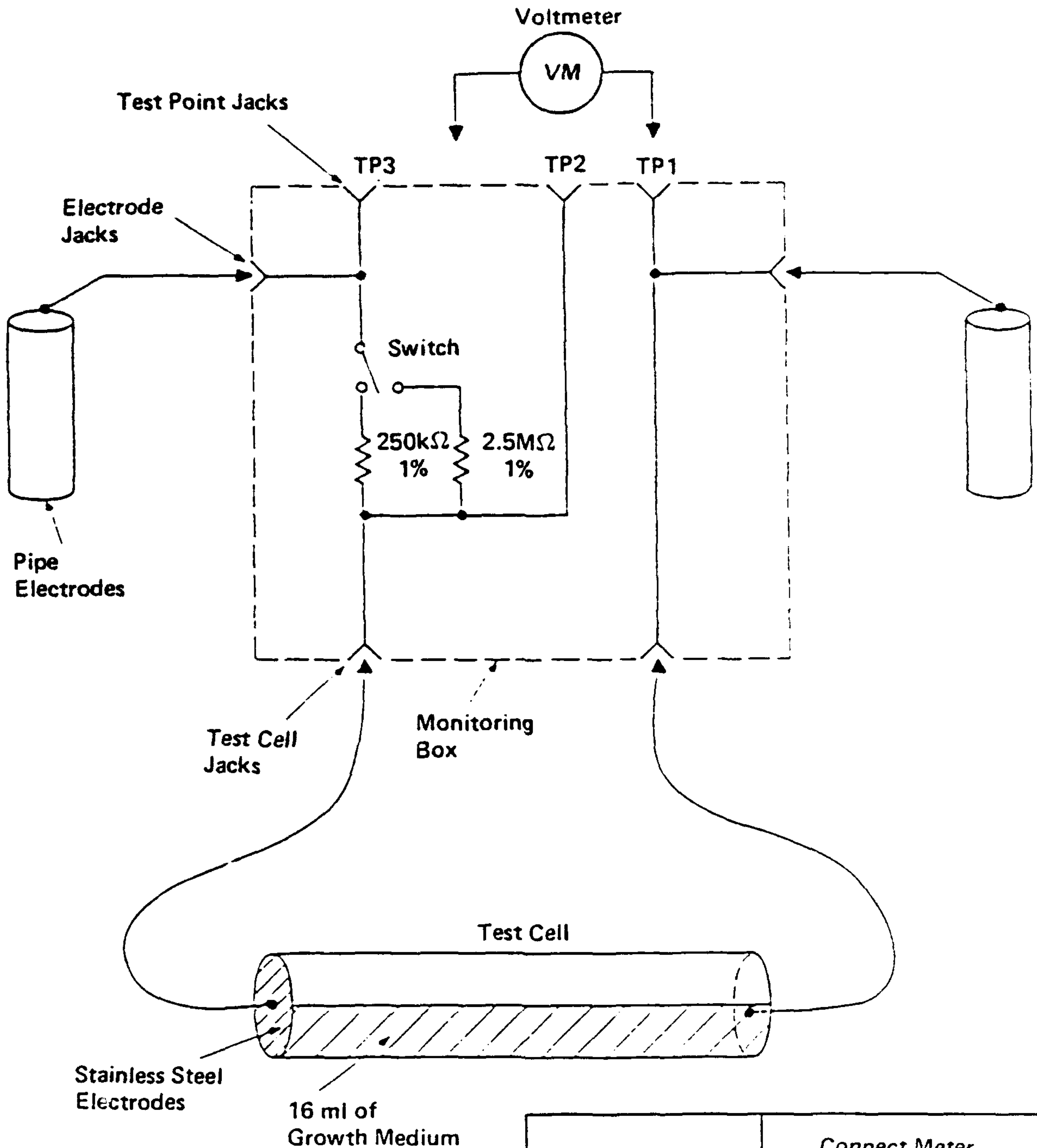
FIGURE J-1. DETERMINATION OF DRIVE VOLTAGE FOR THE SOIL AMOEBA STUDIES MATCHED ELECTRIC FIELD PROTOCOL.



To Measure	Connect Meter Across
V_{CL}	TP1 – TP2
V_R	TP2 – TP3
V_{DR}	TP1 – TP4

FIGURE J-2. TEST CHAMBER HOOKUP FOR THE SOIL AMOEBA STUDIES MATCHED ELECTRIC FIELD PROTOCOL.

60297/790



To Measure	Connect Meter Across
V_{CL}	TP1 – TP2
V_R	TP2 – TP3
V_{DR}	TP1 – TP3

FIGURE J-3. TEST CHAMBER HOOKUP FOR THE SOIL AMOEBA STUDIES MATCHED CURRENT DENSITY PROTOCOL.

APPENDIX K

SUMMARY OF OPERATION, NRTF-CLAM LAKE AND NRTF-REPUBLIC

SUMMARY OF OPERATION, NRTF-CLAM LAKE AND NRTF-REPUBLIC

The operations of the NRTF-Clam Lake and the NRTF-Republic during 1984-1989 have been summarized in response to requests from investigators for information on operating schedules. The summary is partitioned differently for the two facilities because of differences in their operating modes. The NRTF-Clam Lake is partitioned according to antenna element, modulation, and frequency. The NRTF-Republic is partitioned in a similar manner except that antenna current is included in 1986, 1987, and 1988 summary tables. Discussion and presentation of data from the NRTF-Clam Lake appear below, followed by the same for the NRTF-Republic.

NRTF-Clam Lake

The operating schedule of the NRTF-Clam Lake has been broken down into three antenna conditions: north-south (NS) antenna, east-west (EW) antenna, and both (B) antennas. The NS antenna data represent those times when the NS antenna was operating while the EW antenna was off; the EW antenna data represent those times when the EW antenna was operating while the NS antenna was off; and the B antennas data represent only those times when the NS antenna and the EW antenna were operating simultaneously.

Tables K-1, K-2, and K-3 show the number of hours of operation per month in 1984 for the north-south, east-west, and both antennas, respectively. Equivalent data for 1985 through 1989 are presented in Tables K-4 through K-18. The columns on these tables, labeled with the calendar months, provide a breakdown of the operation of the NRTF-Clam Lake by frequency and signal type. Subtotals are given by signal type. A monthly total is also provided. Yearly total hours of operation by signal type and frequency are given in the "Annual Totals" column.

The bottom row of the tables gives the number of changes in operational mode of the antennas on a monthly and annual basis. These data represent any change in the operating condition of the facility. This would include an initial power up and changes in the antenna current, phase (when both antennas are powered), frequency, and modulation scheme. It does not include the powering down of antennas.

NRTF-Republic

The operating schedule of the NRTF-Republic was broken down into three antenna conditions in 1986, two antenna conditions in 1987 and 1988, and three antenna conditions in 1989. The 1986 conditions were: north-south (NS) antenna, northern east-west (NEW) antenna element, and southern east-west (SEW) antenna element. The 1987 and 1988 conditions were: NS antenna and east-west (EW) antenna. The 1989 conditions were: NS antenna, EW antenna, and both (B) antennas.

Tables K-19, K-20, and K-21 show the number of hours of operation per month in 1986 for the NS, NEW, and SEW antennas or antenna elements, respectively. Tables K-22 through K-25 show the number of hours of operation per month in 1987 and 1988 for the NS and EW antennas, respectively. Tables K-26 through K-28 show the number of hours of operation per month in 1989 for the NS, EW, and B antennas, respectively. The columns of these tables, labeled with calendar months, provide a monthly breakdown of the operation of the NRTF-Republic by antenna current, frequency, and signal type. Subtotals are given by signal type. A monthly total is also provided. Yearly total hours of operation by antenna current, frequency, and signal type are given in the "Annual Totals" column. The bottom row of the tables gives the number of on/off cycles of the antenna element on a monthly and annual basis.

Throughout 1986, 1987, 1988, and early 1989, the NRTF-Republic operated in such a manner as to permit measurement crews to perform field measurements. In this operating mode, the antenna elements were cycled on and off as needed to enable measurements to be made. In 1986, the cycling of the antenna elements was dictated primarily by measurement crews via radio communication with the transmitting site. As testing efforts grew in 1987, 1988, and early 1989, the antenna elements were continuously cycled on and off during testing hours on a 15-minute rotational cycle, as described in Section 4.4.2.3 of this report. This procedure permitted several measurement crews to perform measurements simultaneously.

The last row in the operations summary tables for the NRTF-Republic was changed from "changes in operational mode" used in previous years to "antenna on/off cycles." This new label more accurately describes the nature of the antenna operations. The number of on/off cycles in 1986 was determined by simply summing the cycle entries in the NRTF-Republic log data sheets. Note that this method differs from that used for the 1986 data tables in the 1986* and 1987** reports in that only the powering up and not the powering down of an antenna is included in the number of on/off cycles. In 1987, 1988, and early 1989, the NRTF-Republic operated primarily on a 15-minute rotational cycle broken into three 5-minute segments to accommodate several measurement crews. The summarized log tables routinely provided to IITRI show the beginning and ending times of such cycles. Separate entries are not included for each change of antenna elements during this cycle, nor are deviations from the cycle accounted for. Thus, the exact number of on/off cycles and duration of operating time for

*ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1986. IIT Research Institute Technical Report E06549-37, September 1987, 52 pp. plus appendixes.

**ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1987. IIT Research Institute Technical Report E06595-1, August 1988, 54 pp. plus appendixes.

each antenna element cannot be determined directly from the summarized log data sheets, but were estimated by the procedure described below for 1987, 1988, and early 1989.

The total number of on/off cycles for the two elements was calculated by multiplying the number of hours between the start and finish of the rotational cycling of the antenna elements by 12, since on/off cycles were on a 5-minute (1/12-hr) basis. The total number of on/off cycles was then multiplied by 1/3 to give the number of cycles for either the NS or EW antenna element. This is because one of the three cycles that occur in a single 15-minute cycle will involve the NS antenna element, and one of the three will involve the EW antenna element.

During periods in 1989 when rotational cycling was not used, operational mode changes were summed as they are for the NRTF-Clam Lake, and appear in the on/off cycles row. The monthly operation times for each antenna or antenna element during rotational cycling of the NRTF-Republic were calculated by multiplying the time period of the rotational cycles by one-third. This is because each element was estimated to have a 33% duty cycle during cyclic operation periods.

The estimates of NRTF-Republic operating time and on/off cycles calculated by the above procedures were judged adequate for general use. However, IITRI can obtain exact, minute-by-minute log data for the NRTF-Republic for specific periods as required by the researchers.

TABLE K-1. 1984 OPERATIONS SUMMARY, NRTF-CLAM LAKE: NORTH-SOUTH ANTENNA ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
76	0.94	107.19	--	1.98	7.24	13.85	--	22.10	8.07	1.69	30.17	1.48	194.71
						Mode: Unmodulated Signal							
44	--	1.69	0.05	0.55	0.66	--	0.58	--	1.75	0.08	--	--	5.36
72	0.64	8.65	--	--	0.52	0.30	0.07	16.40	1.50	0.28	0.32	--	28.68
76	3.91	0.21	0.30	4.46	10.35	6.09	11.44	158.38	116.88	9.29	2.28	--	323.59
80	0.81	3.12	1.79	1.06	--	--	0.01	1.97	2.69	2.40	2.91	--	16.76
Subtotals	5.36	13.67	2.14	6.07	11.53	6.39	12.10	176.75	122.82	12.05	5.51	--	374.39
Other[b]	--	0.34	0.21	0.62	0.59	--	--	--	0.05	1.38	0.13	--	3.32
Totals	6.30	121.20	2.35	8.67	19.36	20.24	12.10	198.85	130.94	15.12	35.81	1.48	572.42
Changes in Operational Mode	50	68	14	50	297	71	140	223	163	171	19	2	1268

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-2. 1984 OPERATIONS SUMMARY, NRTF-CLAM LAKE: EAST-WEST ANTENNA ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
44	--	--	--	--	0.82	--	--	--	--	--	--	--	0.82
76	0.64	13.94	18.81	0.92	7.90	0.05	1.45	0.02	2.41	0.33	0.22	0.04	46.73
Subtotals	0.64	13.94	18.81	0.92	8.72	0.05	1.45	0.02	2.41	0.33	0.22	0.04	47.55
						Mode: Unmodulated Signal							
44	5.11	--	--	3.45	--	--	0.53	--	--	0.03	--	--	9.12
72	10.45	2.81	0.18	0.01	0.45	--	0.05	--	--	--	--	--	13.95
76	47.97	5.75	0.77	5.53	18.28	4.20	9.76	1.20	2.78	5.88	--	--	102.12
80	--	--	0.07	17.20	1.19	--	1.36	--	--	--	0.31	--	20.13
Subtotals	63.53	8.56	1.02	26.19	19.92	4.20	11.70	1.20	2.78	5.91	0.31	--	145.32
Other[b]	--	--	3.10	--	0.93	--	--	--	--	0.15	--	--	4.18
Totals	64.17	22.50	22.93	27.11	29.57	4.25	13.15	1.22	5.19	6.39	0.53	0.04	197.05
Changes in Operational Mode	55	32	13	36	273	48	152	50	80	131	3	1	874

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-3. 1984 OPERATIONS SUMMARY, NRTF-CLAM LAKE: NORTH-SOUTH AND EAST-WEST ANTENNAS SIMULTANEOUSLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
					Mode: Modulated Signal[a]								
42	--	--	--	--	--	--	--	--	--	59.69	--	--	59.69
44	--	--	62.73	--	0.82	--	--	--	58.81	38.88	--	--	161.24
46	--	--	--	--	--	--	--	--	--	59.41	--	--	59.41
74	--	--	--	--	--	--	--	--	--	24.43	--	--	24.43
76	366.26	273.90	157.39	343.50	384.98	396.76	392.62	366.05	395.38	256.09	429.86	365.13	4127.92
78	--	--	--	--	--	--	--	--	43.37	--	--	--	43.37
Subtotals	366.26	273.90	220.12	343.50	385.80	396.76	392.62	366.05	497.56	438.50	429.86	365.13	4476.06
					Mode: Unmodulated Signal								
44	--	--	--	--	0.10	--	--	--	--	0.35	--	--	0.45
72	4.14	2.71	2.43	4.05	3.89	2.44	1.88	5.61	2.36	2.64	2.49	3.33	37.97
76	0.03	--	0.05	1.04	3.12	0.05	1.54	42.54	18.03	1.20	0.16	--	67.76
80	4.75	2.70	0.57	2.99	2.13	2.57	2.77	3.61	2.81	1.22	1.85	1.62	29.59
Subtotals	8.92	5.41	3.05	8.08	9.24	5.06	6.19	51.76	23.20	5.41	4.50	4.95	135.77
Other[b]	--	--	0.26	--	0.51	--	--	0.03	0.81	1.28	--	--	2.89
Totals	375.18	279.31	223.43	351.58	395.55	401.82	398.81	417.84	521.57	445.19	434.36	370.08	4614.72
Changes in Operational Mode	67	40	41	85	144	67	79	264	181	94	68	76	1206

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-4. 1985 OPERATIONS SUMMARY, NRTF-CLAM LAKE: NORTH-SOUTH ANTENNA ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: Modulated Signal[a]													
44	--	--	3.41	0.86	0.50	--	--	--	--	--	--	--	4.77
76	0.15	--	3.83	3.21	3.15	3.09	--	1.98	76.31	27.12	--	--	118.84
78	--	--	--	0.33	--	--	--	--	1.87	--	--	--	2.20
Subtotals	0.15	--	7.24	4.40	3.65	3.09	--	1.98	78.18	27.12	--	--	125.81
Mode: Unmodulated Signal													
76	0.40	2.50	5.46	4.79	26.22	29.04	0.68	9.40	9.81	10.41	1.43	0.25	100.39
80	--	--	2.74	3.26	0.02	0.42	--	--	4.14	--	--	--	10.58
Subtotals	0.40	2.50	8.20	8.05	26.24	29.46	0.68	9.40	13.95	10.41	1.43	0.25	110.97
Other[b]	--	--	5.70	1.96	1.20	0.66	0.02	--	4.29	0.03	--	--	13.86
Totals	0.55	2.50	21.14	14.41	31.09	33.21	0.70	11.38	96.42	37.56	1.43	0.25	250.64
Changes in Operational Mode	18	2	32	56	126	115	15	51	42	15	3	1	476

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-5. 1985 OPERATIONS SUMMARY, NRTF-CLAM LAKE: EAST-WEST ANTENNA ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
44	--	--	3.15	3.07	1.34	1.62	--	--	0.34	--	--	--	9.52
76	0.85	--	7.30	14.82	20.69	1.28	142.27	2.23	2.17	3.02	0.03	--	194.66
78	--	--	1.64	0.93	--	--	--	--	0.32	--	--	--	2.89
Subtotals	0.85	--	12.09	18.82	22.03	2.90	142.27	2.23	2.83	3.02	0.03	--	207.07
						Mode: Unmodulated Signal							
76	1.08	2.06	8.94	0.61	40.81	12.87	37.19	10.98	4.76	28.76	3.31	--	151.37
80	--	--	1.50	2.55	3.77	6.55	--	--	1.86	0.13	--	--	16.36
Subtotals	1.08	2.06	10.44	3.16	44.58	19.42	37.19	10.98	6.62	28.89	3.31	--	167.73
Other[b]	0.10	--	5.86	3.94	0.90	5.26	19.13	0.19	1.16	--	--	--	36.54
Totals	2.03	2.06	28.39	25.92	67.51	27.58	198.59	13.40	10.61	31.91	3.34	--	411.34
Changes in Operational Mode	46	1	74	80	143	223	31	59	45	22	3	0	727

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-6. 1985 OPERATIONS SUMMARY, NRTF-CLAM LAKE: NORTH-SOUTH AND EAST-WEST ANTENNAS SIMULTANEOUSLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: Modulated Signal[a]													
44	0.23	--	--	1.97	0.46	0.05	29.73	--	--	--	--	--	32.44
76	0.70	--	7.62	15.01	45.98	261.68	118.66	74.91	161.36	451.69	657.61	730.96	2526.18
78	--	--	--	0.99	--	0.05	73.94	--	0.43	--	--	--	75.41
Subtotals	0.93	--	7.62	17.97	46.44	261.78	222.33	74.91	161.79	451.69	657.61	730.96	2634.03
Mode: Unmodulated Signal													
76	0.34	--	10.16	90.06	10.35	10.70	--	1.63	4.82	3.40	0.61	--	132.07
80	--	--	--	9.80	--	0.98	--	--	--	1.72	--	--	12.50
Subtotals	0.34	--	10.16	99.86	10.35	11.68	--	1.63	4.82	5.12	0.61	--	144.57
Other[b]	0.13	--	25.48	43.63	0.31	0.22	10.87	--	0.03	--	--	--	80.67
Totals	1.40	--	43.26	161.46	57.10	273.68	233.20	76.54	166.64	456.81	658.22	730.96	2859.27
Changes in Operational Mode	13	0	14	60	55	69	15	48	20	54	38	38	424

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-7. 1986 OPERATIONS SUMMARY, NRTF-CLAM LAKE: NORTH-SOUTH ANTENNA ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
76	40.51	11.81	1.37	3.13	0.16	21.20	7.65	3.33	1.88	0.01	0.05	0.94	92.04
Subtotal	40.51	11.81	1.37	3.13	0.16	21.20	7.65	3.33	1.88	0.01	0.05	0.94	92.04
						Mode: Unmodulated Signal							
72	0.00	0.00	0.00	0.29	1.86	0.00	0.00	0.00	0.15	0.00	0.00	0.00	2.30
76	0.00	0.00	0.00	1.22	0.30	0.00	0.00	0.00	0.17	3.28	0.00	0.00	4.97
80	0.00	0.00	0.00	0.42	1.33	0.00	0.00	0.12	0.08	0.00	0.00	0.00	1.95
Subtotals	0.00	0.00	0.00	1.93	3.49	0.00	0.00	0.12	0.40	3.28	0.00	0.00	9.22
Other[b]	0.00	0.00	0.00	0.00	1.46	0.00	0.00	0.00	0.19	0.00	0.00	0.00	1.65
Totals	**40.51**	**11.81**	**1.37**	**5.06**	**5.11**	**21.20**	**7.65**	**3.45**	**2.47**	**3.29**	**0.05**	**0.94**	**102.91**
Changes in Operational Mode	14	5	12	15	77	26	23	10	46	37	2	7	274

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-8. 1986 OPERATIONS SUMMARY, NRTF-CLAM LAKE: EAST-WEST ANTENNA ONLY
[Hours of Operation]

Frequency, Hz	Month Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
						Mode: M. 'ated Signal[a]							
76	0.05	2.81	2.32	0.34	1.86	1.00	2.91	2.58	4.37	2.59	1.65	0.09	22.57
Subtotals	0.05	2.81	2.32	0.34	1.86	1.00	2.91	2.58	4.37	2.59	1.65	0.09	22.57
						Mode: Unmodulated Signal							
72	0.00	0.00	0.00	0.66	1.74	0.00	0.02	0.00	0.00	0.00	0.00	0.00	2.42
76	0.00	0.00	1.10	0.21	1.38	0.00	0.08	0.00	0.00	3.36	0.09	0.00	6.22
80	0.00	0.00	0.00	0.80	0.56	0.00	0.01	0.00	0.00	0.00	0.00	0.00	1.37
Subtotals	0.00	0.00	1.10	1.67	3.68	0.00	0.11	0.00	0.00	3.36	0.09	0.00	10.01
Other[b]	0.00	0.00	0.00	0.00	1.50	0.00	0.00	0.00	0.15	0.00	0.00	0.00	1.65
Totals	0.05	2.81	3.42	2.01	7.04	1.00	3.02	2.58	4.52	5.95	1.74	0.09	34.23
Changes in Operational Mode	47	6	14	24	65	32	20	5	8	18	2	4	245

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-9. 1986 OPERATIONS SUMMARY, NRTF-CLAM LAKE: NORTH-SOUTH AND EAST-WEST ANTENNAS SIMULTANEOUSLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
					Mode: Modulated Signal[a]								
76	672.44	633.09	600.27	595.68	656.56	641.07	689.94	633.20	675.58	688.85	696.57	679.21	7862.46
Subtotals	672.44	633.09	600.27	595.68	656.56	641.07	689.94	633.20	675.58	688.85	696.57	679.21	7862.46
					Mode: Unmodulated Signal								
72	0.00	0.00	0.00	0.00	0.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.89
76	0.15	0.07	7.54	0.00	0.25	0.00	0.00	0.00	0.00	1.80	0.44	0.00	10.25
80	0.00	0.00	0.00	0.00	0.51	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.58
Subtotals	0.15	0.07	7.54	0.00	1.65	0.00	0.00	0.00	0.00	1.87	0.44	0.00	11.72
Other[b]	0.00	0.00	0.00	0.00	1.48	0.00	0.00	0.00	0.33	0.00	0.00	0.34	2.15
Totals	672.59	633.16	607.81	595.68	659.69	641.07	689.94	633.20	675.91	690.72	697.01	679.55	7876.33
Changes in Operational Mode	45	54	69	61	112	72	66	42	63	62	45	61	752

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-10. 1987 OPERATIONS SUMMARY, NRTF-CLAM LAKE: NORTH-SOUTH ANTENNA ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
76	11.03	0.07	0.00	0.09	0.38	0.40	1.88	0.24	0.00	2.13	1.09	0.00	17.31
Subtotals	11.03	0.07	0.00	0.09	0.38	0.40	1.88	0.24	0.00	2.13	1.09	0.00	17.31
						Mode: Unmodulated Signal							
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other[b]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	11.03	0.07	0.00	0.09	0.38	0.40	1.88	0.24	0.00	2.13	1.09	0.00	17.31
Changes in Operational Mode	19	0	2	0	6	8	32	1	1	5	5	1	80

[a] Frequencies listed refer to the center frequency of modulation.

[b] Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-11. 1987 OPERATIONS SUMMARY, NRTF-CLAM LAKE: EAST-WEST ANTENNA ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: Modulated Signal[a]													
76	0.10	0.00	0.00	0.00	11.18	7.30	4.72	0.10	3.27	0.00	1.13	24.60	52.40
Subtotals	0.10	0.00	0.00	0.00	11.18	7.30	4.72	0.10	3.27	0.00	1.13	24.60	52.40
Mode: Unmodulated Signal													
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.17
76	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
8C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.23
Subtotals	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.45
Other[b]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	0.10	0.00	0.05	0.00	11.18	7.30	4.72	0.10	3.27	0.00	1.53	24.60	52.85
Changes in Operational Mode	6	2	1	2	67	6	9	5	3	3	39	5	148

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-12. 1987 OPERATIONS SUMMARY, NRTF-CLAM LAKE: NORTH-SOUTH AND EAST-WEST ANTENNAS SIMULTANEOUSLY
[Hours of Operation]

Frequency, Hz	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
Mode: Modulated Signal[a]													
76	712.70	651.08	658.35	697.30	715.76	691.87	700.54	584.40	697.31	724.71	703.15	695.82	8232.99
Subtotals	712.70	651.08	658.35	697.30	715.76	691.87	700.54	584.40	697.31	724.71	703.15	695.82	8232.99
Mode: Unmodulated Signal													
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	1.77	0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.53	2.76
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03
Subtotals	1.77	0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.56	2.79
Other[b]	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38
Totals	714.85	651.08	658.35	697.30	716.22	691.87	700.54	584.40	697.31	724.71	703.15	696.38	8236.16
Changes in Operational Mode	32	10	11	10	13	14	24	23	13	10	12	12	184

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-13. 1988 OPERATIONS SUMMARY, NRTF-CLAM LAKE: NORTH-SOUTH ANTENNA ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
76	0.00	0.00	0.25	0.55	0.26	27.08	2.71	1.04	0.00	0.02	0.17	0.01	32.09
Subtotal	0.00	0.00	0.25	0.55	0.26	27.08	2.71	1.04	0.00	0.02	0.17	0.01	32.09
						Mode: Unmodulated Signal							
44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00
72	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23
76	0.00	0.00	0.00	0.00	0.00	0.90	0.00	0.03	0.00	2.00	0.08	0.00	3.01
80	0.00	0.00	0.00	0.08	0.00	0.97	0.00	0.00	0.00	0.00	0.00	0.00	1.05
Subtotals	0.00	0.00	0.00	0.31	0.00	1.87	0.00	0.03	0.00	3.00	0.08	0.00	5.29
Other[b]	0.00	0.00	0.00	1.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.21
Totals	**0.00**	**0.00**	**0.25**	**2.07**	**0.26**	**28.95**	**2.71**	**1.07**	**0.00**	**3.02**	**0.25**	**0.01**	**38.59**
Changes in Operational Mode	3	4	0	18	4	21	12	10	9	1	5	2	89

[a]Frequencies listed refer to the center frequency of operation.

[b]Denotes small periods of time at other frequencies or undesignated operation.

TABLE K-14. 1988 OPERATIONS SUMMARY, NRTF-CLAM LAKE: EAST-WEST ANTENNA ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
76	10.93	0.09	0.38	0.10	0.17	0.19	1.07	0.35	0.49	2.31	0.11	0.07	16.26
Subtotals	10.93	0.09	0.38	0.10	0.17	0.19	1.07	0.35	0.49	2.31	0.11	0.07	16.26
						Mode: Unmodulated Signal							
44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.10	0.00	2.10
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.03	3.92	16.14	0.11	0.00	21.20
80	0.00	0.00	0.00	0.00	0.00	1.31	0.15	0.00	0.00	0.00	0.00	0.00	1.46
Subtotals	0.00	0.00	0.00	0.00	0.00	1.31	0.15	1.03	3.92	18.14	0.21	0.00	24.76
Other[b]	0.00	0.00	0.00	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.61
Totals	10.93	0.09	0.38	0.71	0.17	1.50	1.22	1.38	4.41	20.45	0.32	0.07	41.63
Changes in Operational Mode	0	4	5	11	8	9	13	10	2	6	5	34	107

[a]Frequencies listed refer to the center frequency of operation.

[b]Denotes small periods of time at other frequencies or undesignated operation.

TABLE K-15. 1988 OPERATIONS SUMMARY, NRTF-CLAM LAKE: NORTH-SOUTH AND EAST-WEST ANTENNAS SIMULTANEOUSLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: Modulated Signal[a]													
76	716.72	680.73	721.26	699.90	716.52	654.48	685.32	714.15	691.24	660.47	690.78	720.02	8351.59
Subtotals	716.72	680.73	721.26	699.90	716.52	654.48	685.32	714.15	691.24	660.47	690.78	720.02	8351.59
Mode: Unmodulated Signal													
44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.77	0.12	0.00	6.89
72	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40
76	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	14.75	0.07	0.00	14.88
80	0.00	0.00	0.00	0.25	0.00	0.00	1.03	0.00	0.00	0.00	0.00	0.00	21.28
Subtotals	0.00	0.00	0.00	0.71	0.00	0.00	21.03	0.00	0.00	21.52	0.19	0.00	43.45
Other[b]	0.00	0.00	0.00	1.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.17
Totals	716.72	680.73	721.26	701.78	716.52	654.48	706.35	714.15	691.24	681.99	690.97	720.02	8396.21
Changes in Operational Mode	10	10	21	23	11	16	20	19	14	17	19	9	189

[a]Frequencies listed refer to the center frequency of operation.

[b]Denotes small periods of time at other frequencies or undesignated operation.

TABLE K-16. 1989 OPERATIONS SUMMARY, NRTF-CLAM LAKE: NORTH-SOUTH ANTENNA ONLY
[Hours of Operation]

Frequency, Hz	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
	Month												
Mode: Modulated Signal[a]													
44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.05
76	0.00	0.00	0.02	0.08	2.12	0.05	11.68	6.25	1.61	10.71	8.40	390.60	431.52
Subtotal	0.00	0.00	0.02	0.08	2.12	0.05	11.68	6.30	1.61	10.71	8.40	390.60	431.57
Mode: Unmodulated Signal													
44	0.00	0.00	0.00	0.00	0.00	0.18	20.17	20.23	2.80	0.00	0.73	0.00	44.11
72	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07
76	0.00	0.00	1.34	0.54	0.00	0.00	9.64	18.61	2.17	0.00	0.00	0.00	32.30
80	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
Subtotals	0.00	0.00	1.50	0.54	0.00	0.18	29.81	38.84	4.97	0.00	0.73	0.00	76.57
Other[b]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.32
Totals	0.00	0.00	1.52	0.62	2.12	0.23	41.49	45.46	6.58	10.71	9.13	390.60	508.46
Changes in Operational Mode	0	2	39	7	4	9	20	57	29	6	3	41	217

[a]Frequencies listed refer to the center frequency of operation.

[b]Denotes small periods of time at other frequencies or undesignated operation.

TABLE K-17. 1989 OPERATIONS SUMMARY, NRTF-CLAM LAKE: EAST-WEST ANTENNA ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.20
76	0.14	0.18	0.57	0.00	0.17	0.17	0.21	0.10	0.05	0.12	0.00	0.00	1.71
Subtotals	0.14	0.18	0.57	0.00	0.17	0.17	0.21	0.30	0.05	0.12	0.00	0.00	1.91
						Mode: Unmodulated Signal							
44	0.00	0.00	0.00	0.00	0.57	1.42	26.71	19.98	0.72	0.00	0.00	0.00	49.40
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.18
76	0.00	0.00	0.00	0.08	0.00	0.00	9.85	21.62	0.20	0.00	0.00	0.00	31.75
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.06
Subtotals	0.00	0.00	0.00	0.08	0.57	1.42	36.56	41.60	0.92	0.00	0.24	0.00	81.39
Other[b]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.58
Totals	0.14	0.18	0.57	0.08	0.74	1.59	36.77	41.90	0.97	0.12	0.82	0.00	83.88
Changes in Operational Mode	1	1	10	7	5	6	21	46	12	4	8	9	130

[a]Frequencies listed refer to the center frequency of operation.

[b]Denotes small periods of time at other frequencies or undesignated operation.

TABLE K-18. 1989 OPERATIONS SUMMARY, NRTF-CLAM LAKE: NORTH-SOUTH AND EAST-WEST ANTENNAS SIMULTANEOUSLY
[Hours of Operation]

Frequency, Hz	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
	Mode: Modulated Signal[a]												
44	0.00	0.00	0.00	0.00	0.00	0.00	44.03	113.52	0.00	0.00	0.00	0.00	157.55
76	718.32	426.34	714.02	694.58	650.72	479.99	140.97	260.12	488.35	405.23	662.59	300.33	5941.56
Subtotals	718.32	426.34	714.02	694.58	650.72	479.99	185.00	373.64	488.35	405.23	662.59	300.33	6099.11
	Mode: Unmodulated Signal												
44	0.00	0.00	0.00	0.00	17.34	0.00	24.15	46.53	0.00	0.00	0.00	0.00	88.02
72	0.00	0.00	0.11	0.00	3.50	0.00	0.00	0.00	0.00	0.00	0.03	0.00	3.64
76	0.00	0.00	0.73	1.81	1.00	0.00	18.25	63.62	2.62	0.00	0.00	0.00	88.03
80	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.27
Subtotals	0.00	0.00	0.89	1.81	21.84	0.00	42.40	110.15	2.62	0.00	0.25	0.00	179.96
Other[b]	0.00	0.00	0.00	0.00	0.00	0.00	24.00	12.00	23.98	0.00	0.50	0.00	60.48
Totals	718.32	426.34	714.91	696.39	672.56	479.99	251.40	495.79	514.95	405.23	663.34	300.33	6339.55
Changes in Operational Mode	9	7	15	20	35	7	42	77	28	27	43	20	330

[a]Frequencies listed refer to the center frequency of operation.

[b]Denotes small periods of time at other frequencies or undesignated operation.

TABLE K-19. 1986 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH ANTENNA ONLY
[Hours of Operation]

Frequency, Hz	Month Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
Mode: Modulated Signal[a]													
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mode: Unmodulated Signal													
76 (4 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	24.43	16.74	10.71	11.49	0.00	0.00	63.37
76 (6 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.11
76 (10 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	24.43	16.74	10.82	11.49	0.00	0.00	63.48
Other[b]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.07
Totals	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**24.43**	**16.74**	**10.89**	**11.49**	**0.00**	**0.00**	**63.55**
Antenna On/Off Cycles	0	0	0	0	0	0	145	23	31	60	0	0	259

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-20. 1986 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTHERN EAST-WEST ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
						Mode: Modulated Signal[a]							
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
						Mode: Unmodulated Signal							
76 (4 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.11	0.00	0.00	0.00	0.16
76 (6 Amps)	0.00	0.00	0.00	0.00	0.00	18.87	13.80	0.36	2.46	9.15	0.00	0.00	44.64
76 (10 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	18.87	13.80	0.41	2.57	9.15	0.00	0.00	44.80
Other[b]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.06
Totals	0.00	0.00	0.00	0.00	0.00	18.87	13.80	0.41	2.63	9.15	0.00	0.00	44.86
Antenna On/Off Cycles	0	0	0	0	0	55	10	2	26	83	0	0	176

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-21. 1986 OPERATIONS SUMMARY, NRTF-REPUBLIC: SOUTHERN EAST-WEST ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
						Mode: Unmodulated Signal							
76 (4 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.00	0.00	0.00	0.05
76 (6 Amps)	0.00	0.00	0.00	0.00	0.00	11.72	0.00	0.00	5.26	5.76	0.00	0.00	22.74
76 (10 Amps)	0.00	0.00	3.87	18.64	6.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.66
Subtotals	0.00	0.00	3.87	18.64	6.15	11.72	0.00	0.04	5.27	5.76	0.00	0.00	51.45
Other[b]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.03
Totals	0.00	0.00	3.87	18.64	6.15	11.72	0.00	0.04	5.30	5.76	0.00	0.00	51.48
Antenna On/Off Cycles	0	0	27	39	5	6	0	2	30	78	0	0	187

[a] Frequencies listed refer to the center frequency of modulation.

[b] Denotes short periods of time at other frequencies or undesignated operation.

TABLE K-22. 1987 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH ANTENNA ONLY
(Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
						Mode: Unmodulated Signal							
76 (15 Amps)	0.00	0.00	0.00	0.00	0.00	44.40	27.59	32.40	38.86	33.08	21.79	0.00	198.12
Subtotals	0.00	0.00	0.00	0.00	0.00	44.40	27.59	32.40	38.86	33.08	21.79	0.00	198.12
Other[b]	0.00	0.00	0.00	0.42	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.84
Totals	0.00	0.00	0.00	0.42	0.42	44.40	27.59	32.40	38.86	33.08	21.79	0.00	198.96
Antenna On/Off Cycles	0	0	0	1	1	533	331	389	466	397	262	0	2380

[a]Frequency listed refers to the center frequency of operation.

[b]Denotes small periods of time at other currents or undesignated operation.

TABLE K-23. 1987 OPERATIONS SUMMARY, NRTF-REPUBLIC: EAST-WEST ANTENNA ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
						Mode: Unmodulated Signal							
76 (15 Amps)	0.00	0.00	0.00	0.00	0.00	43.95	27.81	32.39	38.61	33.94	21.90	0.00	98.60
Subtotals	0.00	0.00	0.00	0.00	0.00	43.95	27.81	32.39	38.61	33.94	21.90	0.00	198.60
Other[b]	0.00	0.00	0.00	0.25	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67
Totals	**0.00**	**0.00**	**0.00**	**0.25**	**0.42**	**43.95**	**27.81**	**32.39**	**38.61**	**33.94**	**21.90**	**0.00**	**199.27**
Antenna On/Off Cycles	0	0	0	1	1	527	334	389	463	407	263	0	2385

[a]Frequency listed refers to the center frequency of operation.

[b]Denotes small periods of time at other currents or undesignated operation.

TABLE K-24. 1988 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH ANTENNA ONLY
[Hours of Operation]

Frequency, Hz	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
	Mode: Modulated Signal[a]												
76 (75 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	3.27	0.14	0.00	0.00	0.00	0.00	3.41
Subtotal	0.00	0.00	0.00	0.00	0.00	0.00	3.27	0.14	0.00	0.00	0.00	0.00	3.41
	Mode: Unmodulated Signal												
76 (15 Amps)	27.13	26.36	27.14	34.14	41.23	43.27	0.19	0.00	0.00	0.00	0.00	0.00	199.46
76 (75 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	27.62	59.53	34.24	52.86	12.67	23.76	210.68
44 (75 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	1.27	0.00	26.16	2.61	31.20	15.68	76.92
Subtotals	27.13	26.36	27.14	34.14	41.23	43.27	29.08	59.53	60.40	55.47	43.87	39.44	487.06
Other[b]	0.00	0.00	0.00	0.00	0.00	0.00	8.09	0.00	0.00	0.00	0.00	0.00	8.09
Totals	27.13	26.36	27.14	34.14	41.23	43.27	40.44	59.67	60.40	55.47	43.87	39.44	498.56
Antenna On/Off Cycles	326	316	326	410	495	519	485	714	725	666	526	473	5981

[a]Frequency listed refers to the center frequency of operation.

[b]Denotes small periods of time at other currents or undesignated operation.

TABLE K-25. 1988 OPERATIONS SUMMARY, NRTF-REPUBLIC: EAST-WEST ANTENNA ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
76 (15 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	3.32	0.14	0.00	0.00	0.00	0.00	3.46
Subtotal	0.00	0.00	0.00	0.00	0.00	0.00	3.32	0.14	0.00	0.00	0.00	0.00	3.46
						Mode: Unmodulated Signal							
76 (15 Amps)	27.14	30.95	31.48	34.34	41.33	43.13	0.22	0.00	0.00	0.00	0.00	0.00	208.59
76 (75 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	31.10	68.99	34.71	56.05	12.67	23.76	227.28
44 (75 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	1.06	0.00	26.38	2.52	31.29	15.58	76.83
Subtotals	27.14	30.95	31.48	34.34	41.33	43.13	32.38	68.99	61.09	58.57	43.96	39.34	512.70
Other[b]	0.00	0.00	0.00	0.25	0.42	0.00	7.20	0.00	0.00	0.00	0.00	0.00	7.20
Totals	27.14	30.95	31.48	34.34	41.33	43.13	42.90	69.13	61.09	58.57	43.96	39.34	523.36
Antenna On/Off Cycles	326	371	378	412	496	518	526	827	733	703	527	472	6289

[a]Frequency listed refers to the center frequency of operation.

[b]Denotes small periods of time at other currents or undesignated operation.

TABLE K-26. 1989 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH ANTENNA ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
44	0.00	0.00	0.00	0.00	0.19	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.20
76	0.00	0.00	0.00	0.00	6.91	0.00	0.00	0.05	0.85	0.00	19.00	0.00	26.81
78	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32
Subtotals	0.00	0.00	0.00	0.00	7.42	0.00	0.01	0.05	0.85	0.00	19.00	0.00	27.33
						Mode: Unmodulated Signal							
44	8.02	22.24	12.28	0.86	0.43	0.60	4.51	14.16	0.00	0.00	0.15	0.00	63.25
72	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.48	0.00	0.00	0.00	0.00	0.75
76	37.53	21.16	8.19	0.30	3.82	0.42	9.19	25.30	3.55	0.00	0.00	0.00	109.46
80	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.38
Subtotals	45.55	43.40	20.47	1.16	4.25	1.67	13.70	39.94	3.55	0.00	0.15	0.00	173.84
Other[b]	0.00	0.00	0.00	0.00	0.40	1.24	0.35	0.02	0.00	0.00	0.00	0.00	2.01
Totals	45.55	43.40	20.47	1.16	12.07	2.91	14.06	40.01	4.40	0.00	19.15	0.00	203.18
Antenna On/Off Cycles	547	521	245	2	30	73	9	24	97	1	7	0	1556

[a]Frequency listed refers to the center frequency of operation.

[b]Denotes small periods of time at other currents or undesignated operation.

TABLE K-27. 1989 OPERATIONS SUMMARY, NRTF-REPUBLIC: EAST-WEST ANTENNA ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
44	0.00	0.00	0.00	0.00	0.11	0.20	0.29	0.00	0.00	0.00	0.00	0.00	0.60
76	0.00	0.00	0.00	0.00	1.85	0.13	0.48	0.00	0.34	23.70	0.00	0.00	26.50
78	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13
Subtotals	0.00	0.00	0.00	0.00	2.09	0.33	0.77	0.00	0.34	23.70	0.00	0.00	27.23
						Mode: Unmodulated Signal							
44	8.02	22.24	12.53	0.00	0.60	0.94	5.2	11.78	0.29	0.00	0.00	0.00	61.60
72	0.00	0.00	0.00	0.00	0.00	0.82	0.52	0.00	0.00	0.00	0.00	0.00	1.34
76	37.56	21.16	8.11	2.65	4.78	1.57	9.22	17.83	13.68	0.00	0.00	0.00	116.56
80	0.00	0.00	0.00	0.00	0.00	0.59	0.85	0.00	0.00	0.00	0.00	0.00	1.44
Subtotals	45.58	43.40	20.64	2.65	5.38	3.92	15.79	29.61	13.97	0.00	0.00	0.00	180.94
Other[b]	0.00	0.00	0.00	0.00	1.00	0.99	2.16	0.00	0.00	0.00	0.00	0.00	4.15
Totals	45.58	43.40	20.64	2.65	7.47	4.25	16.56	29.61	14.31	23.70	0.00	0.00	212.32
Antenna On/Off Cycles	548	521	246	1	32	70	57	17	70	2	13	1	1578

[a]Frequency listed refers to the center frequency of operation.

[b]Denotes small periods of time at other currents or undesignated operation.

TABLE K-28. 1989 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH AND EAST-WEST ANTENNAS SIMULTANEOUSLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
44	0.00	0.00	0.00	0.00	23.99	26.03	69.78	51.97	0.00	0.36	0.00	0.00	172.13
76	0.00	0.00	0.00	0.00	56.09	0.84	96.42	229.01	345.51	679.61	690.11	743.38	2840.97
78	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.35
Subtotals	0.00	0.00	0.00	0.00	80.11	26.87	166.2	280.98	345.51	680.29	690.11	743.38	3013.45
						Mode: Unmodulated Signal							
44	0.35	1.12	0.61	4.30	119.33	76.04	82.41	49.14	7.18	0.00	0.47	0.00	340.95
72	0.00	0.00	0.00	0.00	0.42	1.64	0.46	0.02	0.07	0.00	0.00	0.00	2.61
76	1.04	1.84	7.37	2.95	125.65	389.56	354.51	121.39	164.37	9.70	4.97	0.00	1183.35
80	0.00	0.00	0.00	0.00	6.05	24.75	0.00	46.03	0.09	0.00	0.00	0.00	76.92
Subtotals	1.39	2.96	7.98	7.25	251.45	491.99	437.38	216.58	171.71	9.70	5.44	0.00	1603.83
Other[b]	0.00	0.00	0.00	0.00	1.30	6.90	4.09	1.69	0.00	29.69	4.68	0.00	48.35
Totals	1.39	2.96	7.98	7.25	332.86	525.76	607.67	499.25	517.22	719.68	700.23	743.38	4665.63
Antenna On/Off Cycles	24	24	16	2	73	125	110	88	145	80	68	55	810

[a]Frequency listed refers to the center frequency of operation.

[b]Denotes small periods of time at other currents or undesignated operation.